THE IMPLEMENTATION OF THE PROTOCOL ON ENVIRONMENTAL PROTECTION TO THE ANTARCTIC TREATY:

THE INTERPLAY BETWEEN LAW AND ENVIRONMENTAL MANAGEMENT

by

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Declaration

Aspects of this thesis have been presented in the following publications:

Cordonnery, L., 1997, Area Protection and Management in Antarctica: A Proposed Strategy for the Implementation of Annex V of the Madrid Protocol based on Information Management, *Environmental Law and Planning Journal*, vol. 14, n° 1, pp.38-51.

Cordonnery, L., 1998, Environmental Protection in Antarctica: drawing lessons from the CCAMLR model for the implementation of the Madrid Protocol, *Ocean Development and International Law*, (forthcoming, issue n° 2).

These publications were the direct result of research conducted as part of the Doctoral programme.

I declare that the work presented in this thesis contains no material which has been accepted for a degree or diploma by the University or any other institution except by way of background information and duly acknowledged in the thesis, and to the best of my knowledge and belief no material previously published or written by another person except where due acknowledgment is made in the text of the thesis.

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Authority of Access

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Abstract

This thesis argues the need to reinforce the legal basis for environmental protection in Antarctica through an analysis of the provisions contained in the Protocol on Environmental Protection to the Antarctic Treaty. An alternative to overcome the current deficiencies of the Protocol is provided through evidenced based information documenting the spatial dimension of the issues at stake. The relevance of using Geographical Information Systems (GIS) for gathering and analysing such information is demonstrated through a case study which provides a methodology for implementing the criteria listed in the Protocol with respect to protected areas designation.

The aim of the research is to integrate the analytical methods of several academic disciplines, namely international environmental law, political science, environmental studies and geographical information systems technology, in order to address the issues associated with the implementation of the Protocol on Environmental Protection to the Antarctic Treaty.

The first part of the thesis analyses the legal and political obstacles to a standardised implementation of the Protocol along with the weaknesses contained in some of the provisions of the Protocol. The key role of the Committee for Environmental Protection (CEP) in the implementation process is emphasised in parallel with that of the Scientific Committee and the Commission of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR). CCAMLR is analysed as an institutional precedent within the Antarctic Treaty System (ATS) and as a model for the institutionalisation of the CEP.

The second part of this thesis analyses the potential relevance of decision support tools such as GIS to the operation of the CEP. The analysis emphasises the use of GIS for developing the new protected area system detailed in Annex V of the Protocol. It relies upon precedents within International and Antarctic Organisations which have recently adopted GIS technology for environmental management purposes.

The third part of this thesis develops a methodology for interpreting and applying criteria for the designation of protected areas listed in Annex V. This methodology focuses upon the use of GIS applied to a case study area, the

Windmill Islands, East Antarctica, where fieldwork was undertaken during the summer 1995-1996. The case study casts light upon the potential of GIS techniques for the implementation of the provisions of the Protocol .

The thesis concludes that the current provisions of the Protocol are insufficient to ensure its standardised implementation throughout Antarctica. The concluding part outlines the benefits of the GIS methodology developed in the case study and advocates its implementation within the institutional context detailed in this thesis, wherein the CEP would play a central role. Recommendations are formulated in which the limitations of the case study outcomes are noted, as are the improvements needed for GIS's full potential for environmental management purposes to be realised.

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List of Acronyms

AAT	Australian Antarctic Territory
ADDS	Antarctic Data Directory System
AMD	Antarctic Master Directory
ANARE	Australian National Antarctic Research Expeditions
ARIS	Australian Resources Information System
ASMAs	Antarctic Specially Managed Areas
ASOC	Antarctic and Southern Ocean Coalition
ASPAs	Antarctic Specially Protected Areas
ATCMs	Antarctic Treaty Consultative Meetings
ATCPs	Antarctic Treaty Consultative Parties
ATPs	Antarctic Treaty Parties
ATS	Antarctic Treaty System
CCAMLR	Convention on the Conservation of Antarctic Marine Living Resources
CEE	Comprehensive Environmental Evaluation
CEMP	CCAMLR Ecosystem Monitoring Program
CEP	Committee for Environmental Protection
CNPPA	Commission on National Parks and Protected Areas
COMNAP	Council of Managers of National Antarctic Programmes

CORINE	Coordinated Information on the European Environment
CRAMRA	Convention on the Regulation of Antarctic Mineral Resource Activities
CSIRO	Commonwealth Scientific and Industrial Research Organisation
DEM	Digital Elevation Model
EC	European Community
EEZs	Economic Exclusive Zones
EIA	Environmental Impact Assessment
ESRI	Environmental Systems Research Institute
GIS	Geographic Information Systems
GOSEAC	Group of Specialists on Environmental and Antarctic Conservation
GPS	Global Positioning System
GRID	Global Resource Information Database
ICAIR	International Centre for Antarctic Information and Research
ICSU	International Council of Scientific Unions
IEE	Initial Environmental Evaluation
IUCN	International Union for the Conservation of Nature
MAB	Man and Biosphere Program
NGOs	Non Governmental Organisations
PADU	Protected Areas Data Unit

RDBMS	Relational Data Base Management System
SCAR	Scientific Committee on Antarctic Research
SCOI	Standing Committee on Observation and Inspection
SPAs	Specially Protected Areas
SSSIs	Sites of Special Scientific Interest
TEWG	Transitional Environmental Working Group
UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNGA	United Nations General Assembly
UTM	Universal Transverse Mercator
VMS	Vessel Monitoring System
WCMC	World Conservation Monitoring Centre

Glossary of terms

Abiotic factors characterised by the absence of life: include temperature, humidity, pH, and other physical and chemical influences.

Attribute non-graphic information associated with a point, line or area element in a GIS.

Biota species of all the plants and animals occurring within a certain area or region.

Biotic factors environmental influences caused by plants or animals; opposite of abiotic factors.

Cell the basic element of spatial information in the raster (grid) description of spatial entities.

Contour a line connecting points of equal elevation.

Correlation two variables are said to be correlated if there is an association between them.

Database a structured organization of records for purposes such as automatically generating up to date reports, and answering ad-hoc queries. A GIS database includes data about the position and the attributes of geographical features that have been coded as points, lines, areas, or grid cells.

Data conversion conversion of data into a form suitable for use in a GIS.

Digital Elevation Model (DEM) a quantitative model of landform in digital form

Digitizing the conversion of analogue maps and other sources to a digital form. This may be point digitizing, where points are only recorded when pointing the cursor and pushing appropriate buttons, or stream digitizing where points are recorded automatically at set intervals of either distance or time.

Ecosystem biotic community and its abiotic environment; the whole earth can be considered as one large ecosystem.

Grid a network of uniformly spaced points or lines for locating positions.

Interpolation process by which a mathematical model is used withpoint data or contour lines to infer elevation at known locations where no ground measurements are available.

Layer a logical separation of mapped information according to theme.

Map projection the basic system of coordinates used to describe the spatial distribution of elements in a GIS.

Metadata metadata is digital information that allows the potential user of spatial data to understand the data's fitness for use. Components of such metadata might include information on database contents, database schema, its source and history, and its quality.

Modelling the representation of the attributes of the earth's surface in a digital database.

Module a separate and distinct piece of hardware or software that can be connected with other modules to form a system.

Ordination process by which plant or animal communities are ordered along a gradient.

Overlay arithmetic overlay in a GIS include such operations such as addition, subtraction, division and multiplication of each value in a data layer by the value in the corresponding location in a second layer. A logical overlay involves finding those area where a specified set of conditions occur (or do not occur) together.

Polygon a multi-sided figure representing an area on a map.

Resolution the smallest standard unit of space for which data are recorded.

Spatial data is a collection of digital records that together represent the distribution of some geographical phenomenon over the surface of the earth.

Variable term used in statistics to indicate a characteristic or property that is possible to measure. Variables may be used to measure outcomes or to explain why a particular outcome resulted. These characteristics are sometimes called explanatory or predictor variables.

Vector a variable with a direction.

adapted from:

Burrough, P.A., 1986, *Principles of Geographical Information Systems for Land Resources Assessment*, Oxford: Clarendon Press, 194 pp.;

Krebs, C. J., 1985, *Ecology: the experimental analysis of distribution and abundance*, New York: Harper & Row Inc. , 800 pp.

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Chapter I

Introduction: Legal, Political and Environmental Dimensions of the Madrid Protocol on Environmental Protection to the Antarctic Treaty

1. Aims of research: Information management and improved environmental decision making as key components in the implementation of the Madrid Protocol

The central hypothesis of this research is that the implementation of the Madrid Protocol relies upon the development of an information management strategy on the basis of which the environmental decision making described in the Protocol can become operational. To support this argument, the traditional flaws of international law will first of all be evidenced in the context of the Antarctic Treaty System (ATS) (this chapter).

Chapter II emphasizes the differences between the provisions of the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) and the Madrid Protocol and analyses CCAMLR's operation in order to outline the flaws contained in the Protocol with respect to the decision making process, enforcement powers and the lack of institutions to protect the Antarctic environment. A comparison between CCAMLR and the Protocol shows that their respective advisory bodies, the Scientific Committee and the Committee for Environmental Protection (CEP), are equally lacking in information management tools as means of collecting and analysing data. As evidenced by CCAMLR's experience such information is an essential prerequisite to the adoption of conservation measures. The dearth of information was particularly severe in the first years of operation of the Scientific Committee which undermined its capacity to deliver informed advice. A similar situation is predictable for the CEP since its requirements for environmental information are not included amongst the provisions of the Protocol.

Chapter III demonstrates the benefits of developing an information management strategy with respect to the new protected area system described in Annex V of the Protocol. Uncertainties in the assessment criteria used for the designation of Antarctic Specially Managed Areas (ASMAs) and Antarctic Specially Protected Areas (ASPAs), along with the lack of enforcement of standardised management procedures, outline the need for information management. An analysis of the role of the Scientific Committee on Antarctic Research (SCAR) and of the reasons for its decline is provided as an indication of the potential difficulties to be encountered by the CEP in fulfilling the new responsibilities described in the Protocol. The use of Geographic Information Systems (GIS) will be outlined as the basis of an information management strategy for regional planning and zoning in order to standardise the management procedures detailed in Annex V of the Protocol.

The following chapters aim to provide a theoretical and practical demonstration of GIS capabilities in order to improve environmental decision making in accordance with the provisions of the Protocol. Chapter IV aims to demonstrate the link between the provisions of the Protocol and GIS capabilities to provide a decision making tool within the framework of the CEP, considering its future role as an advisory body to the ATS. The CEP's need to become capable of delivering informed advice is discussed along with GIS applications relevant to the tasks of the CEP. Precedents in the use of GIS at a continental and multinational scale for natural resource management purposes are provided and the constraints imposed by the establishment of such environmental databases are documented.

Chapters V and VI demonstrate the practical potential of GIS as a tool for implementing the tasks assigned to the CEP, particularly "the operation and further elaboration of the Antarctic protected area system" (Article 12(g) of the Protocol). This is achieved through a case study of the Windmill Islands, Wilkes Land, Antarctica, using environmental data collected in the field with a Global Positioning System (GPS) device which were then loaded into the Windmill Islands GIS database of the Australian Antarctic Division. This case study focuses upon the operation and further elaboration of the Antarctic protected area system, using GIS for implementing the biophysical and cultural criteria listed in Article 3(2) of Annex V of the Protocol. While chapter V describes the methodology, chapter VI analyses the results of the case study.

Chapter VII formulates recommendations for the implementation of the Protocol based on the limitations of the legal framework evidenced in the first part of the thesis and on the alternatives presented by the development of an information management strategy using GIS, as theoretically and practically demonstrated in the second part of the thesis.

2. The significance of the Protocol within International Environmental Law

Signed in 1991, in Madrid, the Protocol on Environmental Protection to the Antarctic Treaty (subsequently referred to as the Madrid Protocol) reflects the rise of global environmental issues on the political agenda of a changing world. The Madrid Protocol received ratification by Japan on 9 December 1997, which was deposited with the United States government on 15 December 1997, and entered into force 30 days thereafter, on January 14, 1998. From a legal perspective, this agreement symbolises the emergence of international environmental law which itself proceeds from the evolution of international society. As Caldwell remarks:

> It is not utopian to believe that the environmental concerns of nations may induce their cooperation more rapidly than have the more conventional issues of international relations such as armaments, monetary exchange, trade, investment, and human rights. The proliferation of environmental conventions since the mid-1960s is evidence of environmental concern among nations and their willingness, at least in principle, to accept mutual obligations for the benefit of others as well as themselves if they do not regard the price as too high[1].

(i) International Environmental Law and its implication for sovereignty in Antarctica

International environmental law is a body of collective agreements among states concerning mutual rights and obligations affecting the environment. As Kiss and Shelton note, "the stated purpose of international environmental law entails significant consequences for the international legal order"[2]. International environmental law relies on ethical and philosophical concepts which appear to be challenging some principles of international law. Indeed, the protection of the biosphere is grounded in the recognition of the interdependence between humans and the natural universe. Thus, the protection of the biosphere is in the common interest of humanity. Just as the scope and scale of many environmental issues transcend the boundaries of national interest and responsibility, so too the aim of international environmental law also reflects such reality, notwithstanding sovereignty

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[1] Caldwell, L.K., 1990, *International Environmental Policy*, Second Edition, London: Duke University Press, p.127.

[2] Kiss, A., Shelton, D., 1991, *International Environmental Law*, Ardsley-on-Hudson, New York: Transnational Publishers Inc., p.18.

claims of states over natural resources. For some authors, such as Kiss and Shelton, in international environmental law, states are seen as exercising the functions necessary to achieve conservation objectives, rather than as possessing inherent sovereign rights. As a consequence of this changing vision of international law, Kiss and Shelton note that the role of states has the potential to be transformed into that of guardians or trustees. However, as the two authors suggest, such an approach presents dangers of destabilization for international law unless international institutions are developed for implementation and supervision of international norms and policies. Such implications have been recognized to a lesser extent within the doctrine: for Blay and Piotrowicz, the implication of international environmental law for national sovereignty is that a country's unsustainable developmental policies can no longer be justified on the basis of sovereignty over natural resources. As they point out, "today, the right of each state to exploit its own natural resources is undoubtedly qualified by the genuine international interest in its environmental implications"[3]. In other words, despite maintaining the principle of sovereignty over natural resources, there seems to be an agreement within the doctrine concerning the limitations placed by new principles of international environmental law over its exercise. From my point of view, such limitations upon the exercise of sovereignty are to be expected with the adoption of the Madrid Protocol.

With the Madrid Protocol, Parties to the Antarctic Treaty have adopted a regulatory framework for all human activities in Antarctica, thereby reinforcing their role as trustees of this continent. In this respect, the Protocol provides a response to the concerns expressed at the United Nations General Assembly (UNGA) over the capacity of Antarctic Treaty Parties (ATPs) to protect Antarctica in the common interest of humanity[4]. Between 1983 and 1988, debates occurred at the UNGA pending the negotiation of the Convention on the Regulation of Antarctic Mineral Resource Activities (CRAMRA) between Parties to the Antarctic Treaty. These debates focused on environmental

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[3] Blay, S., Piotrowicz, R., 1993, Biodiversity and Conservation in the 21st Century: A Critique of the Earth Summit 1992, *Environmental Law and Planning Journal*, Volume 10, 450-469, p.462.

[4] UN, 1991, *United Nations General Assembly Records 46th Session. Report of Secretary-General on the state of the environment in Antarctica*, 25 October 1991, A46/590.

UN, 1992f, *Protecting the Earth's Great Wilderness: Antarctica*. New York: United Nations Department of Public Information, DPI 1222.

UN, 1993f. *Protecting the Common Heritage of Antarctica*. New York: United Nations Department of Public Information , DPI 1375.

protection and the disposition of mineral resources in Antarctica. In 1989, the UNGA adopted a resolution calling for the protection of Antarctica as a nature reserve or world park and urging a ban on prospecting and mining. Furthermore, the resolution emphasized that any regime to be established for the protection and conservation of the Antarctic environment and its dependent and associated ecosystems must be negotiated with the full participation of all members of the international community if it is to gain the level of near-universal acceptability necessary to ensure full compliance and enforcement[5]. However, this resolution was not taken into consideration by Parties to the Antarctic Treaty while negotiating the Madrid Protocol, despite the inclusion of members of Non Governmental Organizations (NGOs) within most delegations. As Wolfrum notes:

History and practice of international law show that a limited group of states may, and have done so in the past, set up a regime in the interest of the international community. This has happened with regard to the specific status of a territory, to demilitarization of a region, to the navigation of a waterway and to the denuclearization of an area. One cannot assume a priori that such regimes serve the interests of the international community to a lesser degree than regimes negotiated in a universal forum[6].

Despite the validity of this observation, one can argue that the ATS remains unrepresentative of the international community in comparison with the United Nations. In this respect, the granting of consultative rights to states acceding to the Antarctic Treaty has been most restricted. For example, it was only after sixteen years that the first new Consultative Party, Poland, was admitted[7]. The rights of accession to the Antarctic Treaty itself are wide: any state of the United Nations may accede. But the Contracting Parties are not entitled to take part in the Antarctic Treaty Consultative Meetings (ATCMs) where recommendations and policies are elaborated. Article IX(2) of the Antarctic Treaty provides that each Contracting Party by accession shall be entitled to Consultative Party status during such time as it demonstrates its interest in Antarctica by conducting substantial scientific research there, such as the establishment of a scientific station or the despatch of a scientific expedition. However, the right of Consultative Parties to withhold consent, which can prevent a Contracting

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[5] U.N. Documents. A/C.1/44/L.69 November 20, 1989.

[6] Wolfrum, R., 1991, *The Convention on the Regulation of Antarctic Mineral Resource Activities.* Berlin: Springer-Verlag. p.86.

[7] For further details about this case, see: Auburn, F.M., 1982, *Antarctic Law and Politics,* Canberra: Croom-Helm (Australia). pp.147-154.

Party achieving Consultative Party status, illustrates the extent to which the Consultative Parties seek to retain control over Antarctic affairs. As Triggs notes:

The contrast between the open rights of accession and the restricted access to the status of Consultative Party with its policy-making role, demonstrates the reluctance of the negotiating states to allow a managerial role in Antarctic affairs to any but those states with a genuine commitment to Antarctic scientific research and exploration[8].

In this context, the legitimacy of the ATS, and its subsequent future, appears to be conditional to a successful implementation of the Protocol and its recognition by NGOs and forums such as the UNGA[9]. The adoption of the Protocol has already deflected the anti-ATS campaign conducted by a lobby of developing nations at the UNGA. In 1994, at the UNGA, non-Antarctic Treaty Parties urged speedy ratification and further strengthening of the Protocol through new annexes (for example, on liability) and the imposition of a permanent ban on mining[10].

(ii) The role of NGOs and the need for institutional cooperation in Antarctica

Traditionally restricted to states as main political actors, international society is now gradually incorporating in its decision making sphere NGOs which are particularly concerned with environmental protection in the case of Antarctica. NGOs have played a major role, at national and international levels, in preventing the occurrence of mineral exploitation and developing public awareness of the importance of protecting the Antarctic environment. NGOs grouped together in the Antarctic and Southern Ocean Coalition (ASOC), encouraged letter-writing campaigns for a ban on minerals activitity and for

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[8] Triggs, G.D., 1986, *International Law and Australian Sovereignty in Antarctica*, Sydney: Legal Books Pty. Ltd, p.165.

[9] Beck, P., 1992, The 1991 UN Session: the environmental protocol fails to satisfy the Antarctic Treaty System's critics, *Polar Record*, volume 28 , n° 167, pp. 307-314.

Beck. P., 1993, The United Nations and Antarctica, 1992: still searching for that elusive convergence of view, *Polar Record*, volume 29 , n° 171, pp. 313-320.

Beck, P., 1994, The United Nations and Antarctica, 1993: continuing controversy about the UN's role in Antarctica, *Polar Record*, volume 30, n° 175, pp. 257-264.

[10] For further details on this issue, see: Beck, P., 1995, The United Nations and Antarctica, 1994: the restoration of consensus ? *Polar Record*, volume 31, n° 179, pp. 419-424.

world park status for Antarctica; ASOC also launched a number of successful international petitions against the ratification of CRAMRA. Information, advice, and strategies were exchanged through the coordinating offices of ASOC and Greenpeace International. Personalities such as the oceanographer Jacques Cousteau, who lobbied publicly and privately politicians and state leaders, attracted considerable media coverage. As a consequence of these actions, the Madrid Protocol, unlike previous Antarctic agreements, benefited from the input of NGOs, which were able to deliver advice in the drafting of the Protocol. This situation reflects the particularity of the environmental protection debate in Antarctica and the increase in public scrutiny of Antarctic politics. As Caldwell notes: "NGOs now provide a continuity in international environmental policy not obtainable through periodic international conferences"[11]. In fulfilling such a task, NGOs are able to identify failures or insufficiencies in program implementation. They will have an important role to play in monitoring the implementation of the Madrid Protocol once it enters into force.

However, while the role of NGOs is particularly important in the identification of cases of non-compliance to agreed rules, it cannot replace the need for institutions that would be responsible for providing continuity in environmental monitoring. As von Moltke notes, the environment needs monitoring and management at an international level, and neither is possible without a minimum of institutional structure. He adds:

> This need for monitoring and management distinguishes environmental issues from most others on the international agenda, which can frequently be handled through the traditional procedural principles of international law that assumes that sovereign states are the legal individuals at an international level[12].

Another aspect of monitoring is to provide opportunities to enhance our understanding of the ecological systems involved and the actions that work to produce the results that the signatories seek. This type of monitoring, as opposed to monitoring in order to identify non-compliance, requires the collection and analysis of different kinds of information, which can only be

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[11] Caldwell, L.K., 1988, Beyond Environmental Diplomacy: the Changing Institutional Structure of International Cooperation, In: (J.E. Carroll, ed.), *International Environmental Diplomacy* , Cambridge: Cambridge University Press, p.23.

[12] von Moltke, K., 1988, International Commissions and Implementation of Law, In: *International Environmental Diplomacy*, op.cit, supra n°11.

gathered within a context of institutional cooperation. As Kiss and Shelton note with respect to environmental monitoring and management:

> These various tasks necessitate a continuity of cooperative structure which can be assured only by permanent institutions. Institutional permanence is necessary also for the development of International Environmental Law. Clearly, elaboration and adherence to international standards are indispensable to prevent deterioration of the environment. In addition, there must be mechanisms to supervise application of rules. By itself, entry into force of standards usually does not and cannot ensure resolution of the problems addressed. Evolution of the state of the environment and knowledge of it requires virtually constant revision of the rules, adapting existing instruments and their application. These tasks also demand sustained cooperation and an institutional framework[13].

While principles of environmental planning, monitoring and management are clearly expressed in the Madrid Protocol[14], the question remains how these principles will be put into practice considering the lack of institutional cooperation still prevailing within the ATS. The interpretation of the Protocol, and the subsequent shaping of an approach to implementation may vary between countries, according to factors such as national environmental standards, the size of its operations, available funding, research traditions and political organization. In this respect, the absence of provisions concerning institutional cooperation can be explained from a historical perspective by describing the diplomatic context of the ATS in which the Madrid Protocol was adopted.

3. The significance of the Protocol within the Antarctic Treaty System

Since its entry into force in 1961, the Antarctic Treaty has expanded into a multilateral regional regime usually referred to as the Antarctic Treaty System[15]. Its principal components include: the Antarctic Treaty itself, the

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[13] Kiss, A., Shelton, D., op.cit, supra n°2, p.55.

[14] Such principles are expressed in the Preamble and in Article 3(2) which states that "(c) Activities in the Antarctic Treaty Area shall be planned and conducted on the basis of information sufficient to allow prior assessments of and informed judgments about, their possible impacts on the Antarctic environment and dependent and associated ecosystems and on the value of Antarctica for the conduct of scientific research"; and "(d) regular and effective monitoring shall take place to allow assessment of the impacts of ongoing activities, including the verification of predicted impacts".

[15] Joyner, C., 1988, The Antarctic Legal Regime: An Introduction, In: (C. Joyner & S.K Chopra,

Agreed Measures for the Conservation of Antarctic Flora and Fauna adopted in 1964, the 1972 Convention on the Conservation of Seals, the 1980 Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR), the 1988 Convention on the Regulation of Antarctic Mineral Resource Activities and the 1991 Protocol on Environmental Protection to the Antarctic Treaty.

However, the ATS does not constitute an international organisation with international personality; it has no standing secretariat and there is no central arrangement for the circulation of information. As Triggs notes, the ATS has been developed to meet particular needs as they arise. In practice the Consultative Parties which are named in the preamble to the Treaty meet every year at a conference hosted and organised by one of the Parties. Such meetings are commonly referred to as Antarctic Treaty Consultative Meetings (ATCMs)[16]. The purposes of ATCMs are to exchange information, to consult together on matters of common interest pertaining to Antarctica, and to formulate recommendations in furtherance of the principles and objectives of the Antarctic Treaty[17].

The Madrid Protocol aims at supplementing the Antarctic Treaty with respect to "the protection of the Antarctic environment and dependent and associated ecosystems" as stated in the preamble[18]. The Protocol has been adopted as a result of the dismissal of CRAMRA and, as Wolfrum notes, while CRAMRA focussed on mineral resource activities, the Protocol embraces some of its features but applies them to the regulation of all human activities in Antarctica[19].

(i) Diplomatic processes leading to the adoption of the Madrid Protocol

Concerns about CRAMRA, which eventually led to its abandonment came from several actors in the international community. ASOC expressed the concern that CRAMRA could not guarantee that the Antarctic environment would remain

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eds.) *The Antarctic Legal Regime*, Dordrecht: Martinus Nijhoff Publishers, pp.1-9.

[16] The agreement to hold future ATCMs on an annual basis was reached at the 16th ATCM in 1991. Previously, ATCMs were held every two years.

[17] Triggs, G.D., 1987, The Antarctic Treaty Regime: Legal Issues, In: (G.D. Triggs, ed.) *The Antarctic Treaty Regime*, Cambridge: Cambridge University Press, pp. 51-56.

[18] Protocol on Environmental Protection to the Antarctic Treaty; XIth Special Consultative Meeting in Madrid. Doc XI ATSCM/2, 21 June 1991, adopted 4 October 1991.

[19] Wolfrum, R., op.cit, supra n°6.

pristine: despite the existence of environmental principles within the Convention, their implementation was never put into practice. This was difficult considering the lack of specificity and definition for threshold terms used in the provisions of the Convention[20]. Moreover, the primary purpose of CRAMRA was not to protect the environment but rather to provide opportunities and guarantees for mineral development. The Convention did not specify where the profits derived from mineral activities in Antarctica would go nor how they might be disposed such that "the interest of all mankind" would be respected, as stated in the preamble of the Antarctic Treaty. This led to criticisms from the UNGA with respect to the lack of participation of the international community in Antarctica (as detailed above). Detractors of CRAMRA also pointed out that if mineral exploitation was permitted, it might lead to disputes over resources between claimant states[21] and sponsoring states operating within some claimed sector, since CRAMRA did not provide privileged payments for mining operations in claimed sectors. As Joyner notes, this could be read as a tacit admission that claimant states were willing to give up full administrative control over their territory[22].

The concerns over the capacity of CRAMRA to protect the Antarctic environment while establishing a safe and favourable regime for mineral exploitation led Australia and France to reconsider their positions during the negotiations. This provided NGOs with the leverage to mobilise public debate and exploit domestic politics to pressure political leaders on the flaws of CRAMRA. In April 1989, the French government called for the minerals negotiations to be reopened since the degree of environmental protection provided by CRAMRA seemed inadequate in the light of the Exxon Valdez accident in Alaska[23]. In May 1989, the Australian government declared that it

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[20] Examples are provided on the lack of precision of terms used in CRAMRA by Joyner. See: Joyner, C., 1995, CRAMRA's Legacy of Legitimacy: Progenitor to the Madrid Environmental Protocol, In: (Blay, Piotrowicz, Tsamenyi, Davis, eds.) *Antarctic and Southern Ocean Law and Policy Occasional Papers 7*, Hobart: Institute of Antarctic and Southern Ocean Studies, University of Tasmania, p.9.

[21] Seven Parties to the Antarctic Treaty (the claimant states) claim territorial sovereignty in Antarctica: the United Kingdom, New Zealand, France, Australia, Norway, Chile and Argentina. Article IV of the Antarctic Treaty preserves the conflicting positions of claimant states, potential claimants and non-claimants by "freezing all territorial claims" in Antarctica.

[22] Joyner, C., op.cit, supra n°15, p.13.

[23] For further details on the motivations of France, see: Cordonnery, L., 1992, *La Diplomatie de l'Environnement en Antarctique,* Unpublished D.E.A Thesis, Department of Political Sciences,

would not sign the Convention since it was now committed to a position that no mining at all should take place in Antarctica. In June 1989 a joint statement from the French and Australian Prime Ministers announced that the two countries would be proposing that Treaty Parties negotiate a comprehensive environmental protection regime along with a ban on minerals activity. As Elliott notes, the Australian and French initiative requested a new approach to environmental decision making within the ATS[24]. The original proposal was to elaborate a legally binding agreement containing environmental principles and a set of clear standards against which all activity in the Antarctic would be judged. Additionally, institutional requirements were set out, including an environmental commission with decision-making powers, a scientific and technical committee, an arbitration body and an inspection and monitoring corps.

Consultative parties had agreed that the issue of comprehensive environmental protection measures would be on the agenda of ATCM XV (scheduled in October 1989). During this meeting, Australia and France received strong support from recent signatories to the Antarctic Treaty[25] and built a coalition of like-minded states through networks of influence. However a strong opposition to any decision-making institution responsible for compliance and monitoring remained to their joint proposal[26]. Following a process of institutional bargaining in which NGOs played a major role (with members included in some national delegations) over four consultative sessions held between November 1990 and October 1991, the Madrid Protocol was adopted. The final version of the Protocol includes four annexes which set out rules and guidelines on specific activities. These are: environmental impact assessment (EIA), conservation of fauna and flora, waste disposal and management and marine pollution. A fifth annex on the Antarctic protected area system was adopted at the ATCM XVI held in Bonn. Article 7 of the Protocol states that any activity relating to mineral resources, other than scientific research, shall be prohibited. The issue of mineral exploitation is therefore brought to an end, at least for the duration of the Protocol. However, this prohibition could be amended after fifty

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University of Paris I - La Sorbonne, Paris, France, 111 pp.

[24] Elliott, L.M., 1994, *International Environmental Politics: Protecting the Antarctic,* New York: St Martin's Press, Inc., 336 pp.

[25] These are: Italy, India, Spain, Austria, Bulgaria, Greece (recent signatories) and Belgium and Poland.

[26] For details of the diplomatic processes leading to the adoption of the Protocol, see Elliott, L.M., op.cit, supra n°24, pp. 163-195.

years from the date of entry into force of the Protocol by a majority of the Parties, "including three-quarters of the states which are Antarctic Treaty Consultative Parties at the time of adoption of this Protocol", as stated in Article 25 (3) of the Protocol.

(ii) Issues raised by the implementation of the Madrid Protocol

The final version of the Madrid Protocol appears to be the result of a compromise characteristic to the weaknesses of the convention-protocol approach. As Susskind and Ozawa remark, "the dynamics of the convention-protocol approach yield 'lowest common denominator' agreements designed to appeal to the largest possible number of signatory states"[27]. The consequence of such a compromise with respect to the lack of institutional cooperation is that it undermines the chances of a successful implementation of the Madrid Protocol. Indeed, while the environmental commission envisaged in the joint version of the Protocol proposed by Australia and France had decision-making powers, the CEP to be created once the Protocol enters into force will be confined to an advisory role only.

The absence of institutions responsible for environmental planning, management and monitoring within the ATS is likely to have implications for the implementation of at least two of the Annexes to the Protocol, Annex I on Environmental Impact Assessment and Annex V on Area Protection and Management. The Protocol, through Annexes II, III and IV, provides guidelines on the protection of Antarctic fauna and flora, waste management and the prevention of marine pollution. In addition to these guidelines the Protocol introduces specific requirements for the circulation and review of waste management plans (Article 9 of Annex III) and permits for the capture of wildlife (Article 3 of Annex II). The protocol also details the type of waste to be removed from the Antarctic Treaty Area (Article 2 of Annex III) and procedures to be followed for waste disposal by incineration, on land and in the sea (Article 3, Article 4, Article 5 of Annex III). The implementation of these regulations is already underway in most Antarctic programs and, because of their relative precision, they do not provide much scope for divergent interpretations.

On the other hand, implementation of Annex V is likely to create controversy

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[27] Susskind, L., Ozawa, C., 1992, Negotiating More Effective International Environmental Agreements, In: (Hurrell, A., Kinsbury, B., eds.) *The International Politics of the Environment: Actors, Interests, and Institutions* , Oxford: Clarendon Press, p.147.

and difficulties in terms of coordinating the different environmental planning and management policies of Antarctic Treaty members. Annex V will provide a review of the protected area system by introducing new mechanisms of environmental protection falling under two categories: ASPAs and ASMAs. In fact, the provisions contained in Annex V reflect the shift from a small scale reservation system to a more comprehensive approach to environmental protection in response to an increase in human presence and adverse impacts on the Antarctic environment. While the designation of an ASPA coincides with the need to "protect outstanding environmental, scientific, historic, aesthetic or wilderness values or ongoing and planned scientific research", the designation of an ASMA aims to "assist in the planning and co-ordination of activities, avoid possible conflicts, improve cooperation between Parties or minimise environmental impacts"[28]. As Kriwoken notes, with increasing human activity more and more specially protected areas will need to be declared. With respect to specially managed areas, there is also an increasing need to incorporate regional environmental planning in order to foster cooperation among Antarctic nations operating in a high-use, environmentally sensitive region. However, in the absence of a CEP with decision-making powers, implementation will depend on voluntary compliance and national legislation[29].

With respect to Environmental Impact Assessment, the Protocol introduces the concept of Initial Environmental Evaluation (IEE) "to determine whether the activity might reasonably be expected to have a significant impact" (Article 2 of Annex I). On the basis of IEEs, proposed activities "likely to have no more than a minor or transitory effect on the environment" could proceed. For proposed activities beyond this level of likely impact, a Comprehensive Environmental Evaluation (CEE) needs to be prepared following the guidelines of Article 3, Annex I. However, the Protocol does not provide criteria for determining whether proposed activities would have a significant impact on the Antarctic environment. The word 'significant' is not defined either. In practice, the initial decision of whether to "proceed forthwith" or to require an IEE or CEE is left to the discretion of the national Antarctic operator. The need for independence in the evaluation process is quite obvious in this context. But the Protocol only provides the CEP with an advisory role on "the application and implementation of the environmental impact assessment procedures set out in

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[28] Respectively Article 3(1) and Article 4(1) of Annex V to the Protocol.

[29] Kriwoken, L., 1994, Antarctic Environment and Joint Protection, *Forum for Applied Research and Public Policy*, volume 9, n° 1, p.86.

Article 8 and Annex I" (Article 12 of the Protocol); whereas the institutional framework of CRAMRA had substantial power in the EIA process through the Commission[30]. As Lyons notes:

For reasons related partly to the territorial sovereignty issue and to the balance of power in the Treaty System, the Antarctic Treaty Consultative Parties have not been keen to assign too much real power to any multi-member body or appointed expert over national activities[31].

In this context, the implementation of the Protocol raises a number of issues with respect to information management and improved decision making. The aims of this research are to demonstrate that the development of an information management strategy is conditional to an efficient environmental decision making process and that both aspects are essential to a successful implementation of the Protocol.

4. The challenge of multidisciplinary research: combining environmental law with environmental science

It will be clear from this introduction that the approach chosen to undertake this research is a multidisciplinary one. This can be justified by the nature of the subject: indeed, the understanding of environmental matters and of reasons for discrepancies between theory and practice of environmental protection, in Antarctica as elsewhere, encompasses the analysis of the legislation, the institutional framework in which it takes place and its implementation on the ground, along with the acquisition and review of essential data coming from other fields, such as environmental science. According to the definition provided by Caldwell, environmental science is a metadiscipline in that:

To the extent that a body of knowledge and method can be described as syncretic

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[30] Article 21.1(a) of the CRAMRA details the function of the Commission as follows: "to facilitate and promote the collection and exchange of scientific, technical and other information and research projects necessary to predict, detect and assess the possible environmental impact of Antarctic mineral resource activities, including the monitoring of key parameters and ecosystem components".

Convention on the Regulation of Antarctic Mineral Resource Activities, 1988, In: *Final Report and Final Act of the Fourth Special Antarctic Treaty Consultative Meeting on Antarctic Mineral Resources*, Wellington (2 May-2 June 1988).

[31] Lyons, D., 1993, Environmental Impact Assessment in Antarctica under the Protocol on Environmental Protection, *Polar Record*, volume 29, n° 169, pp. 111-120.

environmental science, it might more accurately be regarded as a metadiscipline, a level of research and teaching that incorporates elements from other disciplines yet is more than the sum of its parts[32].

If environmental science has an important role to play in providing information to the decision making process, this metadiscipline deserves further attention as an alternative to the traditional flaws of international law when it comes to assessing the effectiveness of environmental protection agreements. This research thus intends to demonstrate the benefits to be gained from combining environmental science with environmental law in order to address a number of issues raised by the implementation of the Madrid Protocol. As the Australian Science and Technology Council notes in a report to the Prime Minister:

> One of the greatest barriers to understanding environmental processes is the fragmented knowledge and synthesis within the diversity of contributing research. This fragmentation is due in large part to traditional university departmental structures and associated discipline cultures, and the narrowness of conventional disciplinary-based research programs[33].

This thesis therefore attempts to depart from the fragmentation of knowledge described above, by demonstrating the potential of the latest technology currently used for natural resources management, GIS, in order to overcome implementation difficulties in environmental protection. Indeed, the analysis of the provisions of the Protocol and of the operation of the Antarctic Treaty System reveals traditional deficiencies in international law and the need for information tools to support the decision making process. As we have seen, evidence of such deficiencies are provided by Susskind and Ozawa with respect to the weaknesses of the Convention-Protocol approach yielding "lowest common denominator agreements"[34]. Deficiencies are also noted by Caldwell with respect to the difficulty of enforcing provisions which are usually sought through negotiation and diplomacy rather than adjudication[35]. In the end, informed decisions remain to be taken at a political level, for decisions are taken arbitrarily whilst the claims of sovereignty prevail over other considerations.

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[32] Caldwell, L.K., 1990, *Between Two Worlds: Science, the Environmental Movement and Policy Choice*, Cambridge: Cambridge University Press, 224 pp.

[33] Australian Science and Technology Council, 1990, *Environmental Research in Australia: the Issues. A Report to the Prime Minister by the ASTEC*, Canberra: Australian Government Publishing Service, 87 p.

[34] Susskind, L., Ozawa, C., op.cit, supra n° 27, p.147.

[35] Caldwell, L.K., 1990, op.cit, supra n°1 , p.118.

Chapter II:

The protection of the Antarctic environment: drawing lessons from the CCAMLR model for the implementation of the Madrid Protocol

1. Introduction

CCAMLR's contribution to international environmental law is characterized by the multi-species ecosystem approach it has adopted for the management of living marine resources. The area of application of the Convention coincides with the natural boundary of the Southern Ocean: the Antarctic Convergence[36].

In comparison with the Madrid Protocol, CCAMLR remains a resource management agreement dominated by the conflict of values and interests between conservationist and fishing states over the implementation of the principles of the ecosystem approach. This conflict is not necessarily present in the Madrid Protocol, which seeks to regulate human activities and minimize their impact upon the environment, while putting aside the issue of mineral resources exploitation. The objectives of the Madrid Protocol thus seem less conflictual than the ones of CCAMLR and their implementation should not be obstructed by national interests to the same degree as is apparent in CCAMLR when it comes to the adoption and enforcement of conservation measures.

However, a comparison between the institutions created by CCAMLR and the Madrid Protocol shows major differences in decision making and enforcement powers to the detriment of the Protocol. It will be argued that this constitutes a major obstacle to the implementation of the Protocol. On the other hand, within their respective advisory competencies, the Scientific Committee of CCAMLR

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[36] Article I (1, 2 and 3) of CCAMLR, In: *Handbook of the Antarctic Treaty System*, Eighth Edition, April 1994, US Department of State, p.178

Scully defines the Antarctic convergence as follows: "the Convergence of Polar Front, as it is often called, is a transition zone within which colder Antarctic waters from the south mix with and sink below warmer sub-Antarctic waters from the north. It represents a significant environmental barrier that many species do not cross and has been viewed as the northern boundary of purely Antarctic populations". See: Scully, R.T., 1993, Convention on the Conservation of Antarctic Marine Living Resources, In: (Sherman, K., Alexander, L.M., Gold, B.D., eds.) *Large Marine Ecosystems: Stress, Mitigation and Sustainability*, Washington, D.C: American Association for the Advancement of Science, p.244.

and the CEP created by the Protocol are equally lacking in information and means of collecting data, and this seriously impedes the capacity of both bodies to provide relevant advice. These similarities and differences suggest the usefulness of an analysis of how CCAMLR's operation since 1982 can be used as a model for the implementation of the Madrid Protocol's provisions.

2. The respective contributions of CCAMLR and of the Madrid Protocol to the protection of the Antarctic environment

Both CCAMLR and the Madrid Protocol constitute a legal response to the threats represented by an increased scale of human activity in the Antarctic region. Because the Antarctic Treaty contained no specific provisions in this respect, additional instruments had to be developed to protect the Antarctic environment. Both CCAMLR and the Madrid Protocol contribute to and reflect the evolution of international environmental law by setting up new principles of conservation which may be generalised to other geographical areas and environmental issues in the near future.

Because of Antarctica's specific characteristics, experiments in environmental protection in Antarctica have a considerable likelihood of success. Amongst these characteristics are the absence of indigenous populations and the establishment of a demilitarised and nuclear free zone (established in the Antarctic Treaty in 1959) which has preserved Antarctica from some of the potential conflicts experienced elsewhere. As Dalziell remarks:

> In addition to its scientific importance, Antarctica provides scope for unparalleled political innovation on a global scale. The continent does not have permanent indigenous populations or cultures. As a consequence, many real and perceived confounding factors -potential jobs losses and the desires and needs of local residents- which make environmental protection more difficult elsewhere, are absent. [37]

When Antarctic Treaty Parties had to address the issue of how to protect the Antarctic environment, two different approaches, corresponding to particular challenges faced at different times, were chosen.

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[37] Dalziell, J., Goldsmith, L., 1994, World Park Antarctica: Does It Have a Future?, *Forum for Applied Research and Public Policy*, Volume 9, n° 1, p.71.

(i) How to protect the Antarctic environment: the CCAMLR model

With CCAMLR, Antarctic Treaty nations opted for a 'sustainable development' approach to environmental management via the creation of a resource exploitation regime. During the 1970s the development of the krill fishery gave rise to concerns that unregulated exploitation of krill (*Euphausia superba*), which forms the basis of the Antarctic food chain, would jeopardize the whole Antarctic marine ecosystem unless appropriate measures were taken[38]. Indeed, as noted by Gulland, "the real concern which led to the establishment of CCAMLR was less for krill or fish in themselves, than for the impact that a large-scale krill fishery might have on those species that feed on krill"[39]. It is because of this specific characteristic of the Antarctic marine environment, the dependence on krill of other marine living resources, that an ecosystem approach was adopted rather than the single species approach inherent to most fisheries agreements[40]. Indeed there is considerable spatial and temporal overlap between the krill fishery and krill predators. In the Antarctic Peninsula and the South Orkney Islands, 50 to 90 per cent of the krill catches between December and March are taken in areas within 100 kilometers of predator colonies during the critical period (breeding season, pre-moult period of adults, post-fledging period) when animals have a limited foraging range[41].

The ecosystem approach of CCAMLR thus represents the accommodation of interests between conservationist and fishing states through management principles combining resource exploitation with environmental protection; fishing is still permitted, but regulations aiming to ensure a rational exploitation of resources apply. This regime aims to prevent a decrease in the size of harvested populations to levels that threaten their stable recruitment, and to minimize the risk of changes in the marine ecosystem that are not

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[38] It is widely accepted that unregulated exploitation of krill would have jeopardized the Antarctic marine ecosystem in the long term, see for example: Frank, R., 1983, The CCAMLR, *Ocean Development and International Law Journal*, volume 13, n° 3, p.316.

[39] Gulland, J.A. 1987, The Antarctic Treaty System as a Resource Management Mechanism, In: (G.Triggs, ed.), *The Antarctic Treaty Regime: Law, Environment and Resources*, Cambridge: Cambridge University Press, p.120.

[40] About the importance of krill in the food chain, see the introductory note to the Conservation of Antarctic Marine Living Resources, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 36, p.170.

[41] Kock, K. H., 1994, Fishing and Conservation in Southern Waters, *Polar Record*, volume 30, n° 172, pp. 3-22.

potentially reversible over two or three decades. Harvesting should be regulated by including consideration of the effects of fishing on not only target but also dependent and related species[42].

This ecosystem approach is unprecedented in international fishery management, but so is the establishment of a major fishery at such a low level in the food chain where the effects upon dependent species are largely unknown. Consequently CCAMLR had to incorporate innovative principles of management if it was to be effective. Moreover, the reason for adopting an ecosystem approach stems from the recognition of the inadequacy of methodologies for fisheries management which deal with target species only and ignore other species in the food web[43].

CCAMLR's ecosystem approach is reflected in the area of application of the Convention, where the natural boundary of the Antarctic Convergence is used rather than some artificial delimitation which would have stemmed from political interests. The Antarctic Convergence is defined as a line varying between 60°S and 45°S which means an extension of the Convention area beyond the limits to which the Antarctic Treaty applies[44]. Moreover, the Convention applies to all marine living resources defined in Article I(2) as "finfish, molluscs, crustaceans and all other species or living organisms, including birds, found south of the Antarctic Convergence".

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[42] Article II(3) of CCAMLR, which defines the Convention's principles of conservation of the Convention, includes (a) prevention of decrease in the size of any harvested populations to levels below those which ensure its stable recruitment. For this purpose its size should not be allowed to fall below a level close to that which ensures the greatest annual increment; (b) maintenance of the ecological relationships between harvested, dependent and related populations of Antarctic marine living resources and the restoration of depleted populations to the levels defined in sub-paragraph (a) above; and (c) prevention of changes or minimization of the risk of changes in the marine ecosystem which are not potentially reversible over two or three decades, taking into account the state of available knowledge of the direct and indirect impact of harvesting, the effect of the introduction of alien species, the effects of associated activities on the marine ecosystem and of the effects of environmental changes, with the aim of making possible sustained conservation of Antarctic marine living resources.

[43] Powell, D.L., 1983, Scientific and Economic Considerations Relating to the Conservation of Marine Living Resources in Antarctica, In: (Vicuna, F. O., ed.), *Antarctic Resources Policy*, Cambridge: Cambridge University Press, p.113.

[44] Article I (4) of CCAMLR, op.cit, supra n° 36, p.179.

This reference to the Antarctic Convergence is essential to the implementation of CCAMLR's objective - the protection of all marine living resources. Indeed, all Antarctic marine species are to be found in the area corresponding to the Southern Ocean up to where warm waters meet the cold waters from the Antarctic; this major ecosystem boundary, the Antarctic Convergence, is subject to variation, which makes its choice as boundary an even more novel and inspired decision. At the same time, this helps to demonstrate the capacity of international environmental law to adjust its legal principles to the practical issues to be addressed. In this case, the protection of the Antarctic marine environment requires an ecosystem approach so that all ecological parameters are taken into account; specifically the natural habitat of Antarctic marine species which is delimited by the Antarctic Convergence.

One major contribution of CCAMLR to international environmental law is the establishment of a permanent structure to give effect to the Convention's aims and objectives. In the context of the ATS, this created a precedent, since the agreement to set up a Secretariat, a supervisory Commission and an advisory Scientific Committee for CCAMLR specifically was the Treaty's first empowerment of a subsidiary organisation charged with furthering specific Treaty aims[45]. On the basis of scientific information and advice provided by the Scientific Committee, the Commission formulates, adopts and reviews conservation measures each year[46]. These measures regulate the opening and closing of areas and seasons for fishing, impose total allowable catch numbers for harvested species, and implement other restrictions such as mesh sizes[47].Since 1991, the Commission has expanded the scope of the conservation measures by attempting to minimise the incidental mortality of seabirds in the course of longline fishing in the convention area[48]. The Commission also adopted a conservation measure on the regulation of the use and disposal of plastic packaging bands on fishing vessels in which a substantial number of Antarctic fur seals have been entangled and killed[49]. Additional conservation

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[45] These institutional arrangements are expressed in Article XIII for the Secretariat; Article VII, VIII and IX for the Commission, and, Article XIV to XVI for the Scientific Committee of CCAMLR.

[46] Article IX, paragraph 1(f) of CCAMLR, op.cit, supra n°1, p.181.

[47] Article IX, paragraph 2 of CCAMLR, op.cit, supra n°1, p.181

[48] Conservation Measure29/X, *Schedule of the Conservation Measures in Force 1991/92* , Hobart: CCAMLR Secretariat, p.12.

[49] Conservation Measure 63/XV, *Schedule of Conservation Measures in Force 1996/97*, Hobart: CCAMLR, p. 11.

measures include the notification that members are considering initiating a new fishery[50] and the establishment of monthly catch reporting systems[51]. In 1996, the Commission noted that "the use of a System of Vessel Monitoring (VMS) within the Convention area should be a goal of the Commission at the next meeting"[52]. An observation and inspection system is also provided as part of the enforcement mechanism, as expressed in Article XXIV of CCAMLR. The Standing Committee on Observation and Inspection (SCOI) also agreed that VMS was a useful and highly effective means of enhancing compliance with fisheries conservation measures. Indeed, the use of VMS for all fishing vessels within the Convention area would reinforce the effectiveness of the CCAMLR regime, providing a consensus was reached within the Commission on this issue in the near future. In total, the Commission has adopted one hundred and seventeen conservation measures since the entry into force of the Convention. However, "many conservation measures are designed to have a seasonal influence as they impose limitations on catch which are subject to annual review"[53]. Consequently, only forty three conservation measures were recorded as having a continuing effect at the fifteenth meeting of CCAMLR in 1996. Compliance with conservation measures is required from the Parties which are legally bound to them, as expressed in Article IX (6) and Article XXI of CCAMLR.

In important respects, the provisions of the Convention impose more obligations upon the Parties than is the case with most international agreements: in particular the conservation measures adopted by the Commission, the role of which is to ensure a rational exploitation of Antarctic marine living resources[54]. The conservation measures are essential tools for sustainable long term exploitation of Antarctic marine resources. They provide fishing quotas, applicable to specific zones, prohibition of fishing in case of

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[50] Conservation Measure 31/X, *Schedule of Conservation measures in Force 1991/92*, Hobart; CCAMLR Secretariat, p.15.

[51] Conservation Measure 40/X, *Schedule of the Conservation measures in Force 1991/92*, Hobart: CCAMLR Secretariat, p. 23.

[52] CCAMLR, *Report of the Fifteenth Meeting of the Commission*, 21 October - 1 november 1996, Hobart: CCAMLR Secretariat, p. 28.

[53] Rothwell, D.R., 1996, *The Polar Regions and the Development of International Law*, Cambridge: Cambridge University Press, p. 130.

[54] Article II of CCAMLR states that "the objective of the Convention is the conservation of Antarctic marine living resources" (paragraph 1); "For the purpose of this Convention, the term 'conservation' includes rational use" (paragraph 2).

depleted stocks, and all the appropriate measures required on the basis of scientific information about the state of the marine environment. Furthermore, the Scientific Committee has sponsored work into methods for assessing the impact of fishing on krill stocks, along with a program to monitor the impact of krill fishing on krill predators with the establishment of the CCAMLR Ecosystem Monitoring Program (CEMP)[55]. It is worthwhile noting that some aspects of the CEMP involve monitoring Adelie penguin populations which are breeding on the Antarctic coast, in areas adjacent to fishing grounds. Even though the operation and the decision making process of CCAMLR have major flaws (to be discussed at length later in the chapter), this institutional framework does provide scope for the implementation of the Convention. The creation of a secretariat charged with gathering scientific information derived from fishing activities, the input of the Scientific Committee in its advisory role, and the institutional capacity of the Commission to adopt conservation measures can be seen as prerequisites for ensuring that monitoring takes place in accordance with the goals of the Convention.

However, conservation measures can only be formulated on the basis of scientific information on the impacts of fisheries upon ecosystems. As Powell, former Executive Secretary of CCAMLR, notes:

> The Commission has interpreted the Convention as requiring management decisions to flow directly from scientific advice. This interpretation places a responsibility on the Commission to ensure that the information necessary for the implementation of the Convention is gathered[56].

Lack of data and the consequent scientific uncertainty provide powerful arguments for reluctant Parties to not adopt proposed conservation measures. This situation is significantly undermining the prospects for successful implementation. It also contradicts the ecosystem approach of CCAMLR, which should logically rely on the precautionary principle. This principle has been included in the Rio Declaration (Principle 15) as follows: "In order to protect the environment, the precautionary approach shall be widely applied by states according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for

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[55] Powell, D. L., 1990, Antarctic Marine Living Resources and CCAMLR, In: (Herr, R.A; Hall, H.R; Haward, M.G, eds.) *Antarctica's Future, Continuity or Change?* Hobart: Australian Institute of International Affairs, pp.61-70.

[56] Powell, D.L., op.cit, supra n° 55, p.69.

postponing cost-effective measures to prevent environmental degradation"[57]. Although the Rio Declaration has no normative status in international law, it nonetheless acknowledges the recognition of the precautionary principle by the international community, as it applies to sustainable development and conservation issues. In the context of CCAMLR, the implementation of the precautionary principle would shift the burden of proof from conservationist states to those engaged in fishing activities. Fishing states would thus be required to establish that their activities do not have significantly adverse impacts if those activities are to be permitted to continue at the same level. But, in the absence of scientific data upon which a management policy for fisheries could be developed, the implementation of the precautionary principle has been difficult, at least during the first ten years of CCAMLR's operations. For example, no precautionary catch quotas for krill were adopted by the Commission until 1991. It is only at the 10th meeting of the CCAMLR that the Commission adopted the conservation measure 32/X, establishing precautionary catch limitations on *Euphausia superba,* whereby: "the total catch of *Euphausia superba* in Statistical Area 48 shall be limited to 1.5 million tones in any fishing season. A fishing season begins on 1 July and finishes on 30 June of the following year. This limit shall be kept under review by the Commission, taking into account the advice of the Scientific Committee"[58]. In 1992, precautionary catch limits on krill were extended to Statistical Division 58.4.2 corresponding to Prydz Bay, and Statistical Sub-areas 48.3 which include the Antarctic Peninsula, South Orkney Islands, South Georgia, South Sandwich Islands, Weddell Sea and Bouvet Island region[59].

The delay in the adoption of precautionary catch limits on krill, which were adopted eleven years after the Convention was signed, reveals the difficulty of implementing a precautionary approach in the management of fisheries. It demonstrates that CCAMLR is a resource exploitation regime which reflects the relative political strength and different interests of the conservationist and fishing states. Joyner captured the implications of such a resource exploitation regime in the following comment:

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[57] Rio Declaration on Environment and Development, June 14, 1992, *International Legal Materials,* 31:874.

[58] CCAMLR, *Schedule of Conservation Measures in Force 1991/1992,* Hobart: CCAMLR Secretariat, p.17.

[59] Conservation Measure 45/XI and 46/XI, *Schedule of Conservation Measures in Force 1992/1993,* Hobart: CCAMLR Secretariat, pp.32-33.

CCAMLR places the onus on non-fishing nations to prove that continued exploitation, or 'rational use', is causing harm to a particular species or to the ecosystem as a whole. The ecosystem approach would be better served - and cannot be implemented without - the basic premise maintaining that burden of proof must rest with fishing states[60].

In short, the innovative principles which characterize the ecosystem approach of CCAMLR have been successfully translated into the creation of institutions such as the Scientific Committee and the Commission; the latter however are undermined in their functioning by divergent political interests between Parties. These divergences are mostly felt in the decision making system of the Commission which will be discussed in the second part of this chapter. As Boczek remarks, CCAMLR is "a compromise document with limitations which may have an adverse impact upon the functioning of the conservation regime"[61].

(ii) How to protect the Antarctic environment: The Madrid Protocol model

In comparison, the Madrid Protocol, adopted a decade after CCAMLR, contains principles of environmental protection which should not be subject to similar limitations in terms of implementation. Several factors justify this hypothesis. Firstly, the objectives of the Protocol differ from those of CCAMLR in so far as the Protocol does not create a resource exploitation regime. The Protocol focuses upon the regulation of scientific and logistic activities in order to minimize human impacts upon the environment. Article 3(2.a) of the Protocol states that "activities shall be planned and conducted so as to limit adverse impacts on the Antarctic environment and dependent and associated ecosystems". Additionally, divergence between conservation and resource exploitation stakeholders is unlikely to impair the implementation of the Protocol since Article 7 imposes a moratorium of fifty years on minerals exploitation. Secondly, with the Protocol the burden of proof is reversed. Since it is assumed that all human activities are likely to cause an impact upon the environment, Parties have to undertake an environmental impact assessment before activities can proceed (Article 3.2(c)). The precautionary principle is thus

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60Joyner, C., 1992, *Antarctica and the Law of the Sea*, Dordrecht: Martinus Nijhoff Publishers, p.244.

61 Boczek, B.A., 1984, The Protection of the Antarctic Ecosystem, *Ocean Development and International Law Journal*, volume 13, n° 3, p.375.

receiving a better translation under the Protocol than it has had in CCAMLR. Thirdly, the Protocol has its origins in the 1988 Convention for the Regulation of Antarctic Mineral Resource Activities (CRAMRA) which gave theoretical permission for mining. This Convention failed to be ratified, despite its environmental provisions, when it became clear that a mineral exploitation regime was inconsistent with the protection of the Antarctic environment. In this rejection process, CCAMLR was the only precedent for a resource exploitation regime to which Antarctic Treaty Parties could refer; and, the difficulties experienced in the adoption of conservation measures within CCAMLR might have revealed the risks of establishing a similar resource exploitation regime focusing on Antarctic minerals. As pointed out by Joyner:

> CCAMLR has often been viewed as a precedent for negotiating a minerals treaty. The latter's pitfalls became clear, and it was precisely these deficiencies that prompted more intensive efforts by environmental groups and governments like France and Australia to have Antarctica converted into the equivalent of a world park, since protection appeared to be impaired under a regime in which governments retained control over resources[62].

However, during the Protocol's negotiations, the opposition of "pro-mining" Antarctic Treaty nations to a permanent ban on mineral exploitation revealed the fragility of the concept of "a natural reserve devoted to peace and science" as stipulated in Article 2 of the Protocol. This fragility is institutionalised in the form of Article 25.2 of the Protocol: fifty years after coming into force the Protocol will be subject to a review of its functioning, to amendment and to modification which will allow scope for the issue of mineral exploitation to again be raised. Furthermore, Article 25.5(a) stipulates that, in case of amendment or modification, the moratorium on mineral exploitation will continue "unless a compulsory regime governing such activities is agreed upon between Antarctic Treaty Parties". Explicit reference to such a regime appears to strongly foreshadow a future revival of CRAMRA. Indeed, one may argue that fifty years is about the timetable required to develop cost-effective exploitation techniques and to precisely locate exploitable mineral deposits. Furthermore, the emphasis put on science since the 1959 Antarctic Treaty is reaffirmed in Article 3.3 of the Protocol. This may justify the adoption of scientific research on mineral exploration, which is allowed under Article 7 of the Protocol.

Insofar as the prospect of mineral exploitation has not been indefinitely put

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62 Joyner, C., op.cit, supra n°60, p.254.

aside, the Protocol may be seen as the outcome of a final compromise between "pro-mining" and conservationist states, even though, unlike CCAMLR, the purpose of the Protocol is not to define a resource exploitation regime. It is important to acknowledge the existence of this compromise in order to establish the need for developing means of implementing the Protocol provisions whilst the absence of economic pressure to undertake mineral activities still allows such an opportunity.

Indeed, the key provisions of Article 3 of the Protocol are borrowed from Article 4 of CRAMRA[63]. But the fundamental difference is that CRAMRA 's provisions only relate to the narrow issue of mineral resource activities and the extent to which they are likely to affect the environment. According to Blay:

> The provisions in Article 3 of the Protocol are comprehensive in the proper sense; they introduce a basis for a uniform standard to assess all human activities on the continent, irrespective of whether the activity is related to mining or to scientific research[64].

Comparison of the environmental principles contained in CCAMLR and in the Protocol should also note the potential overlap of the two regimes. Because the Protocol aims to establish a comprehensive environmental protection regime applicable to all Antarctic activities, it is likely that some environmental principles will conflict with fishing activities (for example). Article 5 of the Protocol emphasizes the compatibility of the Antarctic Treaty System (ATS) with the Protocol, so it should not be possible for its implementation to be prevented by an ATS instrument, such as CCAMLR. On the other hand, this provision means that the CCAMLR Commission should take into account the more stringent environmental principles contained in the Protocol for the management of Antarctic marine living resources. For example, will the concept of "stable recruitment for harvested species", currently used by CCAMLR in fisheries management, be compatible with the implementation of Article 3(2.b.iv) of the Protocol[65]? This concept, defining a level of harvesting close to that which ensures the greatest net annual increment for harvested species, has

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63 Article 4 of the Convention on the Regulation of Antarctic Mineral Resource Activities, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n°36, p.206.

64 Blay, S., 1992, New Trends in the Protection of the Antarctic Environment, *American Journal of International Law*, volume 86, p.389.

65 Article 3(2.b.iv) of the Protocol states that "activities in the Antarctic Treaty area shall be planned and conducted so as to avoid: detrimental changes in the distribution, abundance and productivity of species or populations of species of fauna and flora".

been criticized as contradictory to the CCAMLR's ecosystem approach. Indeed, the stable recruitment of krill, for example, may not be high enough to ensure the stable recruitment of dependent species such as fish, squid, seals, whales and seabirds (some of which nesting on the Antarctic coast, in the area of application of the Protocol). More generally, as explained by Auburn, "it is not enough to ensure that prey populations do not fall below levels safeguarding their own stable recruitment, because these levels may not be high enough to protect and ensure stability of dependent species at a higher level in the food chain".[66]

In such a case, how is the Protocol likely to modify the attitude of the CCAMLR Commission with respect to conservation measures defining catch levels? To answer this question one needs to examine the institutional arrangements set in place to implement the environmental principles contained in both CCAMLR and the Protocol.

The Protocol provides an institutional arrangement in the form of an advisory body, the Committee for Environmental Protection (CEP), whose role is to provide guidelines on the implementation of the Protocol. In comparison with the institutional arrangements of CCAMLR, the functions of the CEP are of a limited scope: to advise ATCMs on specific issues related to environmental protection. Furthermore the CEP has no supervisory power, unlike the CCAMLR Commission. A complete analysis of the CEP's role in the implementation of the Protocol will be elaborated in the third part of this chapter; at present, reference to the CEP is only made in relation to potential conflicts between the Protocol and CCAMLR's provisions. In such a case, an institutional response will be required from either the Commission or the CEP.

Article 12 of the Protocol defines the functions of the CEP as follows: "the Committee provides advice and formulates recommendations to the Parties in connection with the implementation of this Protocol for consideration at the Antarctic Treaty Consultative Meetings". Article 11 of the Protocol refers to the report presented by the CEP to each ATCM which "shall cover all matters considered at the sessions and shall reflect the views expressed... The report shall be circulated to the Parties and observers attending the session, and shall thereupon be made publicly available". Confined to an advisory role then, the CEP may only influence decisions taken by the CCAMLR Commission through reports made publicly available. The requirement of publicity provides an

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[66] Auburn, F. M., 1982, *Antarctic Law and Politics* , Canberra: Croom-Helm (Australia), 361 pp.

opportunity for NGOs to become informed and to add their pressure upon CCAMLR. However, critical assessments formulated by the CEP will only induce change if there is political willingness on the part of the CCAMLR Commission to consider them.

The comprehensive approach of the Madrid Protocol regarding the regulation of all human activities in Antarctic, as detailed in Article 3.1 and 3.2, has the potential to interfere with the current interpretation of the ecosystemic principles contained within CCAMLR. However, the CEP, in comparison with the CCAMLR Commission, has been provided with little means of implementing more stringent principles. The paradox is that the CCAMLR Commission alone is able to adopt legally binding conservation measures whilst the CEP can only deliver advice, and even that must be directly addressed to ATCM, not CCAMLR. As Rothwell notes:

> While some provisions of the Protocol reinforce the CCAMLR regime, there is the potential for some of the environmental principles in article 3 of the Protocol to conflict with similar principles which are being interpreted and applied by the CCAMLR Commission. When such an event does occur, it will be interesting to see how the ATS interprets the true aspects of article 4 and article 5 of the Protocol[67].

3. Traditional flaws within International Law and Implications for CCAMLR and the Protocol

Traditionally, the dynamics of the convention-protocol approach have reinforced the tendency to seek lowest common denominator agreements. The final draft often incorporates vague language, so that the duties of parties are not clearly expressed, and with key terms left undefined, thus allowing scope for different interpretations. This situation induces reluctant countries to sign, though it consequently may reduce the chances of effective implementation. The extent to which such flaws are to be found in CCAMLR and the Protocol, and what their consequences are in terms of environmental protection, is the next question to be addressed.

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[67] Rothwell, D.R., 1992, The Madrid Protocol and its Relationship with the ATS, *Antarctic and Southern Ocean Law and Policy Occasional Papers* 5, Hobart:: Institute for Antarctic and Southern Ocean Studies (IASOS), University of Tasmania, p.14.

As noted by Joyner, Paragraph 3 of Article 2 (of CCAMLR) embodies the ecosystem concept by stipulating conservation principles. It does so, however, in a way that remains open to interpretation based on whether one is disposed to favor harvesting or conservation of resources[68]. Examples of phases which would have benefited from a more precise definition are: "the prevention of decrease in the size of any harvested populations to levels below those which should ensure its stable recruitment" (Article II(3.a) of CCAMLR), "the maintenance of ecological relationships" (Article II(3.b) of CCAMLR), and "the prevention of changes or minimization of risk of changes to the marine ecosystem" (Article II(3.c) of CCAMLR). Implementation of these concepts would require an extensive knowledge of population dynamics, ecological relationships between harvested and non-harvested species, and a monitoring program to be in place in order to detect changes in the marine ecosystem. It would then be possible to set appropriate figures and models complementary to these concepts. They cannot, indeed, be implemented otherwise. Because of their vague formulation, they can only be used as guidelines, not as legally binding rules, with only limited scientific knowledge to support them at present. In the context of such poor information, a consensus could not be reached within the Scientific Committee with respect to the recommendations to be forwarded to the Commission. This situation characterizes the initial phase of CCAMLR's operations during which the lack of dialogue between the Scientific Committee and the Commission prevented some conservation measures (such as the ones on krill) to be adopted. In this context, it is not surprising that no conservation measures were adopted until the third meeting of CCAMLR when waters within 12 miles of South Georgia were closed to fishing and a mesh size regulation was adopted[69]. Similarly, with respect the establishment of precautionary limits on the krill catch, a proposal discussed at the 8th meeting of CCAMLR in 1989, arguments pointed to the lack of scientific information available on krill catches and their effect on predators and young fish. In the report of the eighth meeting of the Commission, it is noted that:

Some Members of the Scientific Committee felt it was now appropriate for the Commission to consider the implications of imposing a precautionary limit on the krill catch in Sub-area 48.3. It also noted that other Members of the Scientific Committee expressed doubts about this view. It

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[68] Joyner, C., op.cit, supra n°60, p.231.

[69] Heap, J.A., 1991, Has CCAMLR Worked? Management Policies and Ecological Needs, In: (Jorgensen-Dahl, A., Ostreng, W., eds.) *The Antarctic Treaty System in World Politics*, Basingstoke: MacMillan Academic and Professional, pp.43-53.

was emphasized in the Commission's discussion of this issue that there was insufficient scientific information about the effect of krill catches in Subarea 48.3 on dependent predators and its effect in taking young fish as a by-catch[70].

However, it is unlikely that information on krill, or on any other harvested stock, will be ever free from uncertainties. As Nicol notes, the Commission must devise methods to take into account this uncertainty when making decisions on management [71]. In 1993, the Commission finally endorsed the conclusions of the Scientific Committee with respect to management under conditions of uncertainty. These were:

Under conditions of increasingly poor data availability, management measures would most appropriately start to follow options from a choice of precautionary low catch levels as specific advice on total allowable catches from traditional assessments became less available[72].

With respect to the duties of the Parties, CCAMLR clearly mentions at least three of them: to contribute to the financial support of the Commission[73], to supply scientific data[74], and to comply with the regulations of the Commission[75]. However, the duty to supply scientific data is defined as "to the

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70 CCAMLR, *Report of the Eighth Meeting of the Commission*, 6-17 November 1989, Hobart: CCAMLR Secretariat, p.10.

71 Nicol, S., 1991, CCAMLR and its Approaches to Management of the Krill Fishery, *Polar Record* volune 27, n°162, pp. 229-36.

72 CCAMLR, *Report of the Twelfth Meeting of the Commission*, 25 October-5 November 1993, Hobart: CCAMLR Secretariat, p.10.

73 Article XIX (3) of CCAMLR states that "each Member of the Commission shall contribute to the budget. Until expiration of five years after entry into force of this Convention, the contribution of each Member of the Commission shall be equal. Thereafter the contribution shall be determined in accordance with two criteria: the amount harvested and an equal sharing among all members of the Commission. The Commission shall determine by consensus the proportion in which these two criteria shall apply", In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 36, p. 184.

74 Article XX of CCAMLR, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 36, p.184.

75 Article XXI of CCAMLR states that "each Contracting Party shall take appropriate measures within its competence to ensure compliance with the provisions of this Convention and with conservation measures adopted by the Commission to which the Party is bound in accordance with Article IX of this Convention", In : *Hanbook of the Antarctic Treaty System*, op.cit, supra n°36, p. 185.

greatest extent possible"[76] which undermines fishery management since no precise information was initially required from the Parties. For example, the Scientific Committee identified a number of stocks which had been exploited but for which no data were available, and others where data were insufficient for stock assessments to be made[77]. This situation partly improved in 1987, when a catch reporting system was established for *Champsocephalus gunnari* as part of the conservation measures adopted during the 6th meeting of CCAMLR[78]. Nonetheless, the overall consequences of such vague language have been evidenced by Frank as follows:

> The weak duty imposed upon contracting Parties to supply data and information to the greatest extent possible raises the grave danger of permitting harvesting and conservation decisions to be made with insufficient knowledge about the effects of harvesting on target and dependent species[79].

To illustrate this remark, the Scientific Committee noted that "at the 1986 meeting Members carrying out fisheries in the Subarea 48.3 took the position that any such limitations of catch for the 1986/87 season should be fixed at the level of catch for 1985/1986 season and indicated that they did not intend to exceed these limits"[80]. However, "despite this statement, catches of several fish species in 1986/1987 had greatly exceeded those in 1985/1986. In relation to the high catches of *Champsocephalus gunnari*, the Soviet delegation pointed out that they had informed the Committee at its 1986 session that recruitment to this stock was likely to be high"[81].

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[76] Article XX (1) of CCAMLR states that "the Members of the Commission shall, to the greatest extent possible, provide annually to the Commission and to the Scientific Committee such statistical, biological and other data and information as the Commission and Scientific Committee may require in the exercise of their functions", In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 36, p.184-185.

[77] Report of the Fifth Meeting of the Commission, 8-19 September 1986, Hobart: CCAMLR, p. 26.

[78] Conservation Measure 9/VI: Catch Reporting System for *Champsocephalus gunnari* in Statistical Subarea 48.3, Report of the Sixth Meeting of the Commission, 26 October-6 November 1987, Hobart: CCAMLR, pp.20-21.

[79] Frank, R., op.cit, supra n°38, p.316.

[80] CCAMLR, Paragraph 5.31 of the *Report of the Sixth Meeting of the Scientific Committee*, 26 October-6 November 1987, Hobart: CCAMLR Secretariat, p.22.

[81] CCAMLR, Paragraph 5.32 of the *Report of the Sixth Meeting of the Scientific Committee*, 26 October-6 November 1987, Hobart: CCAMLR Secretariat, p.22.

Concerning the duty to comply with the conservation measures of the Commission detailed in Article IX(6), the objection procedure of Article IX(6.c) also undermines effective implementation since, within 90 days of notification, a member may inform the Commission that it is unable to accept the measures in whole or in part. In this case, the conservation measure does not apply to the country that has formulated this request[82]. Cases of non-compliance with conservation measures have also been observed. For example, the catch reporting system for *Champsocephalus gunnari* adopted in the Conservation Measure 9/VI was not enforced in the following season. The report of the seventh meeting of the Commission states that:

The delegation of the United Kingdom drew attention to a failure to comply with Conservation Measure 9/VI, which had come to the Commission's attention during its review of Conservation Measures at this meeting. The Commission emphasised the seriousness of the matter and reminded Members of their obligations under the Convention[83].

Another common deficiency in international law is the tendency for national sovereignty to be asserted, as convenient, over common interests expressed in the goals and objectives upon which signatories have earlier agreed[84]. In the

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[82] Article IX(6.b) states that "conservation measures shall become binding upon all members of the Commission 180 days after such notification, except as provided in sub-paragraphs (c) and (d) below"; paragraph (c) states that "if a Member of the Commission, within ninety days following the notification specified in the measure, in whole or in part, the measure shall not, to the extent stated, be binding upon that member of the Commission"; paragraph (d) states that " in the event any Member of the Commission invokes the procedure set forth in sub-paragraph (c) above, the Commission shall meet at the request of any Member of the Commission to review the conservation measure. At the time of such meeting and within thirty days following the meeting, any Member of the Commission shall have the right to declare that it is no longer able to accept the conservation measure, in which case the Member shall no longer be bound by such measure".

[83] CCAMLR, *Report of the Seventh Meeting of the Commission*, 24 October- 4 November 1988, Hobart: CCAMLR Secretariat, p.37.

[84] An illustration of this remark can be found in the reluctance currently expressed by Australia and the United States to agree with the European Union on standards of pollutant emission released in the atmosphere which are currently responsible for global warming. This is in contradiction with the commitments listed in Article 4 of the United Nations Framework Convention on Climate Change, signed in May 1992, which state that "each of these Parties shall adopt national policies and take corresponding measures on the mitigation of climate change,

Antarctic context, assertions of sovereignty have prejudiced CCAMLR's operations and effectiveness (as illustrated by the difficulty of adopting conservation measures contrary to the fishing interests), and such a situation is likely to occur again with the Protocol. Both CCAMLR and the Protocol are complementary to the Antarctic Treaty, which maintains a status quo regarding territorial claims (as expressed in Article 4 of the Antarctic Treaty). Until now, this compromise has permitted the avoidance of potential conflicts over claims to sovereignty in Antarctica since all claims are frozen, but it has not solved the related problem of prospective Economic Exclusive Zones (EEZs) during CCAMLR's negotiations. The area of application of the Convention was a subject of concern since it potentially interfered with EEZs claimed by some Parties to the Convention, such as France. During the negotiations, France was concerned that Kerguelen and Crozet Islands, over which it asserted undisputed sovereignty, might be deprived of 200-mile zones by the forthcoming regime. The question of the sovereignty of France in Kerguelen and Crozet, and of its EEZ, found a solution with the inclusion of a statement in the Final Act of CCAMLR held in Canberra in May 1980[85]. The implications of such a statement are that French conservation measures adopted before the entry into force of the Convention would remain effective until modified by France, and conservation measures under the Convention can only be applied to the waters adjacent to the islands with French consent. Furthermore, "if France did not so choose, then any conservation measures adopted equally applied to France and would be enforced by France in the waters adjacent to the two islands" [86].

The consequence of such exceptions is to reduce the scope of the ecosystem approach by creating derogations to the implementation of conservation measures. For example, only thirty five out of the forty three conservation measures having a continuing effect in the 1996/97 season are applicable to France[87]. Moreover, such derogations may be applied to other Antarctic

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by limiting its antropogenic emissions of greenhouse gases and protecting and enhancing its greenhouse gas sinks and reservoirs". (United Nations Framework Convention on Climate Change, May 9 1992, *International Legal Materials*, 31: 848).

[85] CCAMLR, Final Act of the Conference on the Conservation of Antarctic Marine Living Resources,Done May 20, 1980, Paragraphs 1-4, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 36, p.174.

[86] Rothwell, D.R., 1996, op.cit, supra n°53 , p. 127.

[87] The following conservation measures are not applicable to Kerguelen and Crozet islands:

EEZs[88]. As Frank remarks: "In the absence of consensus, France and any other state with undisputed sovereignty over an Antarctic island north of 60ºS could promulgate any national measures which it might deem appropriate"[89]. This also reduces the scope of implementation of the system of inspection, since as reported in the fourteenth meeting of the Commission, "France and South Africa reiterated their positions regarding the non-application of the System of Inspection to waters adjacent to the Crozet and Kerguelen, and Prince Edward Islands, in accordance with the statement made by the Chairman of the Conference on the Conservation of Antarctic Marine Living Resources on 19 May 1980"[90].

Another aspect of sovereignty is reflected in the decision making system of the CCAMLR Commission. Substantive decisions, such as the formulation of Conservation Measures, must be made by consensus[91]. Even the very question of whether a matter is one of substance must be treated as a substantive matter, which means that consensus needs to be reached on that question as well[92]. The

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Conservation Measure 64/XII on the application of the conservation measures to scientific research; Conservation Measure 65/XII on exploratory fisheries; Conservation Measure 19/IX on mesh size for *Champsocephalus gunnari* ; Conservation Measure 30/X on net monitor cables; Conservation Measure 29/XV on the minimisation of the incidental mortality of seabirds in the course of longline fishing in the Convention area; Conservation Measure 31/X on notification that members are considering initiation of a new fishery; Conservation Measure 116/XV on new fishery for *Dissostichus eleginoides* and *D. mawsoni* in Statistical Sub-areas 58.6, 58.7 and Statistical Division 58.4.4 in the 1996/97 season (this conservation measure is however applicable to Kerguelen islands); Conservation Measure 117/XV on monthly fine-scale effort and biological data reporting system for trawl and longline fisheries.

(CCAMLR, *Schedule of Conservation Measures in Force 1996/97*, Hobart: CCAMLR Secretariat)

[88] Paragraph (5) of the Final Act of the Conference on the Conservation of Antarctic Marine Living Resources states that "the understandings, set forth in paragraphs 1-4 above, regarding the application of the Convention to waters adjacent to the Islands of Kerguelen and Crozet, also apply to waters adjacent to the islands within the area to which this Convention applies over which the existence of State sovereignty is recognized by all Contracting Parties".

[89] Frank, R., op.cit, supra nº 38, p.308.

[90] CCAMLR, *Report of the Fourteenth Meeting of the Commission*, 24 October- 3 November 1995, Hobart: CCAMLR Secretariat, p. 25.

[91] Article XII of CCAMLR, In: *Handbook of the Antarctic Treaty System*, op.cit, supra nº 36, p. 182.

[92] Article XII(1) of CCAML states that " Decisions of the Commission on matters of substance shall be taken by consensus. The question of whether a matter is one of substance shall be treated as a matter of substance".

consequence is that any state which wants to avoid agreement simply has to withhold its consent. Besides, the objection procedure previously mentioned in Article IX(6.c) of CCAMLR, in conjunction with consensus voting, gives Parties a double veto over Conservation Measures. Furthermore, the Commission is not empowered to set national harvesting quotas. It can only set such constraints on harvesting as limiting catch or effort in the area of application of the Convention in general[93]. Even in such a case, CCAMLR's operations show that the threat of a veto by one or more fishing nations is likely to succeed in preventing the imposition of quotas. The argument then used by fishing nations to prevent the adoption of conservation measures relied upon the lack of scientific data on fish stocks.

One may argue that such flaws are inherent to any resource exploitation regime, whilst similar expressions of national interest will not be expressed within the Protocol, whose goal is to strictly establish an environmental protection regime. If this is true, however, why has the CEP not been granted a stronger role, similar, say, to the supervisory role of the CCAMLR Commission, on matters such as final decisions with respect to Environmental Impact Assessment (EIA), or monitoring of activities already in place? Perhaps Susskind provides the answer when he states:

> Most global environmental agreements worked out through *ad hoc* negotiations include only weak monitoring and enforcement provisions. This, too, is a function of national efforts to maintain not only control over all decisions within their geopolitical borders but autonomy over actions that affect common areas and resources as well.[94]

Indeed, principles for observation and inspection set out in Article XXIV were intended to bolster CCAMLR's enforcement capacity. Article XXIV calls for "procedures for boarding and inspection, procedures for flag state prosecution and sanctions on the basis of evidence resulting from such boarding and inspections". However, as noted by Joyner, "no actions during the first seven years of CCAMLR approached even this minimal level of authority, a situation that had worked largely to benefit fishing nations"[95]. The system of observation and inspection only came into operation during the 1989/90 season, with inspectors designated by Argentina, Chile, the United States and

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[93] Article IX(2.c) of CCAMLR, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 36, p. 181.

[94] Susskind, L., 1994, *Environmental Diplomacy*, Oxford: Oxford University Press, p.21.

[95] Joyner, C., op.cit, supra n° 60, p.246

the Soviet Union. The inspection system is nationally operated which leaves less room for truly independent monitoring: inspectors are appointed by and report to their governments who in turn report to the Commission[96]. Inspections and observations can be carried out by an inspector or observer from one country on fishing or research vessels of other countries[97]. Prosecutions or the imposition of sanctions in respect of violations of measures adopted by the Commission are the responsibility of the flag state of the offending vessel and are to be reported to the Commission[98]. For example, the Soviet Union, during 1990, carried out 118 inspections of its own vessels, one of which resulted in prosecution for violation of a CCAMLR regulation on mesh size. During the 1991/92 season, inspections under the CCAMLR system of inspection were carried out on 18 vessels, 16 of which were conducted by inspectors on board vessels of their own country[99]. Under the Protocol, a similar situation is to be encountered. No institutional inspection or monitoring system is provided. Inspections are made by observers designated by "any Antarctic Treaty Consultative Party who shall be nationals of that Party" under Article 14(2.a) of the Protocol. However, an alternative is offered in the designation of observers "at Antarctic treaty Consulative Meetings to carry out inspections to be established by an Antarctic Treaty Consultative Meeting" as stated in Article 14(2.b) of the Protocol. The reports observers produce are sent for comment to the Party whose station has been visited, reports and comments from the Party inspected are then circulated to all Parties and to the CEP. Finally they are considered at the next ATCM and made publicly available under Article 14(4) of the Protocol.

The option of Article 14(2.b) of the Protocol provides an opportunity for independent inspection to take place since designated observers may not be nationals of the Party inspected. Moreover, the opportunity of public comment made available under Article 14(4) of the Protocol is likely to encourage criticisms of NGOs when evidence of non-compliance with the Protocol will be observed. But the experience of CCAMLR proved the difficulties of implementing inspection and observation provisions which became effective

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96 Article XXIV(2.c) of CCAMLR, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 36, p. 186.

97 Article XXIV(2.b) of CCAMLR, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 36, p. 186.

98 Article XXIV(2.a) of CCAMLR, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 36, p. 186.

99 Kock, K.H., op.cit, supra n° 41, p.14.

after protracted debate, ten years after the Convention was signed. In both cases, the Madrid Protocol and CCAMLR are not attempting to institutionalize an inspection and monitoring system which could be operated more independently by CCAMLR Secretariat and the CEP for the implementation of the Protocol.

Even though the recent developments in the implementation of the inspection system indicate that conservation is being taken more seriously by the Commission, the difficulties experienced by CCAMLR with respect to the need for information prior to decision-making, monitoring and enforcement are likely to be replicated when the Protocol enters into force. As Sands notes:

> The overall deficiency of the Protocol is its failure to depart from the well-trodden path of compliance by national supervision and enforcement. Has it not been a missed opportunity to fail to establish an International Institutional System for inspection, monitoring and enforcement of the generally reasonable, and often enlightened provisions of the Protocol?[100]

4. The need for institutions to monitor human impacts in Antarctica

(i) How the absence of an institutional framework is likely to compromise the implementation of the Madrid Protocol

The regime for monitoring the impact of human activities upon the Antarctic environment is based upon the environmental principles established in Article 3 of the Protocol, and more specifically from the provisions of Annex I dealing with EIA procedures, Annex III focusing on waste management, and Annex V which establishes a protected area system.

As demonstrated above, these provisions are detailed and comprehensive in that they cover most human activities (except for tourism); nonetheless, the question of implementation and how monitoring will take place remains open. Considering the international aspect of human activities in Antarctica, and their dedication, to a large extent, to science, centralization of information through a permanent, institutionalized structure appears to be a logical response to the need for effective monitoring. However, the Antarctic political context works against institutional options because of potential threats to sovereignty. Indeed,

[100] Sands, P., 1992, Epilogue, In: (Verhoeven, J., Sands, P., Bruce, M., eds.), *The Antarctic Environment and International Law*, London: Graham and Trotman, p.184.

sovereignty is largely expressed in Antarctica as autonomy over actions that affect common areas and resources. The reluctance of ATPs to create institutions provided with monitoring and enforcement powers thus conflicts with the issues ATPs are trying to address, and, more specifically, the goal of environmental protection. The example of the CEP and its containment to an advising role clearly demonstrates that ATPs did not intend to establish, within the Protocol, an institutional framework to monitor, except in the narrowest sense of that term, human impacts in Antarctica. However, it will be argued that institutionalization is an essential requirement for the implementation of the Protocol.

This argument is based on a comparison of the functions and limitations of the CCAMLR Scientific Committee and the CEP. Because these two bodies are provided with similar functions, one can draw, from the experience of the first, lessons of relevance for the operational success of the CEP. Limitations can be evidenced, and recommendations can be made in order to make the CEP more effective.

Article 12 of the Protocol defines the functions of the CEP and specifies the matters for which the CEP will be requested to give advice. These are:

(a) the effectiveness of measures taken pursuant to this Protocol;
(b) the need to update, strengthen or otherwise improve such measures;
(c) the need for additional measures, including the need for additional annexes, where appropriate;
(d) the application and implementation of environmental impact assessment procedures set out in Article 8 of Annex I,
(e) means of minimizing or mitigating environmental impacts of activities in the Antarctic Treaty area,
(g) the operation and further elaboration of the Antarctic Protected Area system,
(i) the collection, archiving, exchange and evaluation of information related to environmental protection,
(j) the state of the environment, and
(k) the need for scientific research, including environmental monitoring, related to the implementation of this Protocol.

If Article 12 of the Protocol clearly defines the matter falling under the CEP's competence, it does not mention how the CEP will fulfill its functions: indeed, with no specific funding, no secretariat and no staff, the question is, on what basis will the CEP be able to assess EIA procedures? How will the CEP be able to formulate advice on the collection and evaluation of information related to environmental protection without any means of data collection and analysis? How will the CEP be able to provide advice on the state of the environment if there is no permanent structure to record human impacts and detect changes to the initial state of the environment? The absence of institutional capacity seems therefore to be the strongest limitation to the potential role of the CEP in the implementation of the Protocol.

In comparison, CCAMLR has achieved considerable progress towards that end. In fact, the Commission and its Scientific Committee were the first permanent bodies established by any of the Antarctic agreements. Article XVII of CCAMLR creates an international organisation with headquarters and annual meetings in Hobart, Australia, an executive secretary and a staff. Considering the issue of Antarctic marine living resources exploitation and conservation, these institutional arrangements appear, in retrospect, both essential and compulsory to such a conditional regime. On the other hand, does the issue of environmental protection in the face of rapidly growing human activities in Antarctica not deserve a similar institutional underpinning? Is not the Protocol a conditional regime as well? Insofar as future activities are subject to EIA procedures before they can proceed, and as some present activities are already subject to regulation, namely waste management and procedures to be followed in protected areas, the answer to this question is affirmative. As noted by Burton:

> The objectives of a conditional regime require an institutional capacity to collect and analyse information, particularly with regard to the environment, and to develop and impose environmental controls, including stop-work orders[101].

Failure to provide such structural underpinning constitutes a major contradiction within the Protocol, whose goals indeed reflect contemporary environmental concerns, without being given an institutional capacity to respond that is even the equivalent of CCAMLR's - though the latter was formulated fully a decade earlier.

Another restriction upon the CEP's effectiveness is the question of membership and its implications for the way advice and reports will be formulated. Article

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[101] Burton, S.J., 1979, New Schemes of the Antarctic Treaty: Toward International Legal Institutions Governing Antarctic Resources, *Virginia Law Review*, volume 65, n°3, p.456.

11(2) of the Protocol stipulates that "each Party shall be entitled to be a member of the Committee and to appoint a representative who may be accompanied by experts and advisers". Similarly, Article XIV(2) of CCAMLR links membership of the Scientific Committee to membership of the Commission. It states that "each Member of the Commission shall be a member of the Scientific Committee and shall appoint a representative with suitable scientific qualifications who may be accompanied by other experts and advisers". In both instances, because representatives are appointed by governments, their views are likely to reflect the official position of Parties which does not necessarily coincide with the conservationist approach expressed in the Convention and the Protocol. As Auburn comments with respect to CCAMLR, "the Scientific Committee is controlled by the Commission. There is no attempt at insulation from political decisions, nor is any obligation placed upon the Commission to follow its advice"[102]. This situation seems incompatible with the neutrality the CEP should have when giving advice on EIAs, and consequently, on decisions concerning whether or not proposed activities should proceed.

Also limiting the effectiveness of the CEP and the CCAMLR Scientific Committee is their non-capacity to conduct scientific research or monitoring. With respect to the CEP, its role is limited to formulation of advice on "the need for scientific research, including environmental monitoring, related to the implementation of this Protocol". With respect to CCAMLR, the Scientific Committee is expected to organize data collection and analysis before developing standards for conservation measures. In both cases, scientific research and monitoring is left to the Parties, a situation which has notable deficiencies in terms of data collection and analysis. For example, Joyner has argued that the Scientific Committee relies on data reporting from a variety of national programs holding disparate interests. Fishing nations tend to oppose strict data-reporting requirements, and later claim that data is insufficient for the adoption of conservation measures. Those same states then oppose explicit research instructions meant for the Commission[103]. With respect to the CEP, Article 12 of the Protocol specifies its role in delivering advice on "the collection, archiving, exchange and evaluation of information related to environmental protection". Since the CEP is not empowered to carry out these operations itself, the availability of information will depend to a large extent of the willingness of Parties to provide it.

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[102] Auburn, F.M., op.cit, supra n° 66, p.238.

[103] Joyner, C., op.cit, supra n° 60, p.235.

Thus the CEP and the Scientific Committee are likely to encounter similar data collection problems in terms of lack of standardization, irregular reporting and incomplete accounting of activities. In each instance, the dearth of scientific information prevents well informed judgment for environmental management. Indeed, how could the CEP provide appropriate advice without the relevant ecosystem's baseline information? Furthermore, even if the CEP or the Scientific Committee recommend additional scientific investigations be carried out, this does not necessarily mean that governments will take into account their advice. For example, as Auburn notes with respect to CCAMLR, when the results of such investigations are to be used to develop conservation measures restricting resource development, the reluctance of nations to contribute will be obvious. Scientific research for such purposes is of no benefit to harvesting nations[104].

(ii) How could the institutional role of the CEP be improved to ensure implementation of the Protocol?

This section formulates recommendations for ensuring effective implementation of the Protocol by way of strenghtening the role of the CEP.

The first aspect to be examined is the management role of the CEP. If granted a monitoring capacity, the CEP could improve the management of human activities in order to minimize impacts on the environment. The importance of monitoring in global environmental agreements has been stressed by Susskind as follows:

> Extensive monitoring of each signatory's compliance with the terms of all global environmental treaties is important, not just to ensure that no one gains an advantage through non-performance but also because monitoring is the key to understanding the threats that motivated collective action in the first place and to successfully recalibrating the standards and timetables contained in each treaty[105].

Standardization of information is the first essential prerequisite to monitoring international activities in Antarctica. The CEP could then impose similar reporting formats so that comparison could be made possible. Another aspect of monitoring is the establishment of baseline environmental data which would enable the CEP to detect changes in the state of the environment. In this respect, the capabilities of Geographic Information Systems (GIS) for recording baseline

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[104] Auburn, F.M., op.cit, supra n° 66, p.229.

[105] Susskind, L.E., op.cit, supra n° 94, p.120.

environmental data, and more generally for environmental monitoring and management purposes, need to be considered[106]. The recognition of GIS as a powerful tool for environmental management, particularly applicable in the Antarctic context, stems, in part, from the Group of Specialists on Environmental and Antarctic Conservation (GOSEAC). In March 1992, GOSEAC acknowledged the importance of developing tools for environmental monitoring and reference was made to GIS in a discussion document, as follows:

The development of Geographic Information System (GIS) will allow the integration of multiple datasets for different variables within a specified area. These datasets may then be viewed singly or in combination, to reveal related effects. Sequential datasets may be similarly viewed to show temporal trends and allow predictions of future impacts to be made[107].

Once the standardization of environmental information and the establishment of baseline environmental datasets is achieved, the CEP would then have the requisite knowledge of the different parameters for environmental management and monitoring. However, successful centralization and analysis of data is determined by the method and instruments used to ensure comparison and modelling. In this respect, the analytical capabilities of GIS need to be stressed so that one understands the results this computer based tool can achieve. As Batty states:

The typical functions of the GIS involve the following operations on spatial data: topological operations which transform and generalize two dimensional spatial data; thus producing maps at various levels of aggregation, overlay analysis techniques which combine maps as layers and enable various visual, statistical, and logical operations on the resulting coverages, buffering and related spatial subdivision methods which identify areas conforming to various criteria, elementary statistical operations involved in describing, and smoothing and developing methods of errors and bias in data[108].

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106 A complete definition of GIS along with description of its capabilities and precedents in the use of GIS in natural resources management are to be provided in the following chapters of this thesis.

107 *Environmental Monitoring in Antarctica,* a discussion document prepared by the Council of Managers of National Antarctic Programs (COMNAP) and the Scientific Committee on Antarctic Research (SCAR), March 1992, Unpublished.

108 Bathy, M., 1993, Using GIS in Urban Planning and Policy Making, In: (Fisher, M. N., Nijkamp, P., eds.), *Geographic Information Systems: Spatial Modeling and Policy Evaluation,* Berlin: Sringer-Verlag, p.54.

In short, data in GIS can be considered to represent a model of the real world. GIS capabilities assist the study of environmental processes and impacts, and thus the analysis of the results of planning decisions. If GIS can clearly help the CEP in its advisory role, this development would also add to the value of the work done by the CEP. This contrasts with the current situation of the CCAMLR Scientific Committee whose role is viewed as politicized, to a large extent, because of the insufficiency and disparity in data collection and analysis (as demonstrated above). Powell has described the prospects for modelling the Antarctic marine ecosystem in light of the weak provisions applying to the Scientific Committee role's within CCAMLR. According to him, models ought to be developed to assist the decision making and monitoring of a wider part of the ecosystem. They would provide guidance on the effects of fishing activity and management decisions. Furthermore, serious attempts should be made early in the life of the Scientific Committee to reach understandings on the use of indicators that will be used to describe the ecosystem. This would represent a truly scientific approach to the provision of advice to the Commission[109]. Such an approach contrasts with the reality of CCAMLR's operations (as detailed above) which suggests that the CEP will only experience a different fate to that of the Scientific Committee if management tools enabling monitoring and modelling can be developed and, consequently, give more weight to its advisory role.

Another way of strengthening the role of the CEP would be to adopt the institutional model of CCAMLR for the implementation of the Protocol principles. The institutionalization of the CEP would aim at improving coordination in reporting, information gathering and thus a commonality of advice given. This would imply, first, that the CEP must become a permanent institution, with specific funding, a secretariat and a staff. Decision making powers should then be granted to the CEP with respect to EIA procedures, so that the capacity exists to prevent undesirable activities from going ahead, which is not the case at present. When the CEP is able to decide whether proposed activities will or will not proceed on the basis of the environmental impacts generated, such a decision should not need to be based on consensus, as the example of the CCAMLR Commission has shown that consensus tends to paralyse the decision making process. A majority system of voting is suggested as preferable in order to avoid long term obstruction on important issues.

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[109] Powell, D.L., 1983, op.cit, supra n° 43, p.116.

The inspection and observation system should be extended to EIA procedures, so that on-site investigations of the likely impacts created by proposed activities can be made. The inspection and observation system should also ensure the effectiveness of protected area categorisation, as stipulated in Annex V, so that appropriate measures are taken to protect sites of ecological importance. Finally, the CEP should be composed of independent experts and reflect the concerns of international public opinion on Antarctic environmental protection. Membership of the CEP and designation of inspectors should therefore include representatives of NGOs, which would be a departure from the present situation where NGOS are confined to the status of silent observers.

5. Conclusion

A comparison of the Protocol with CCAMLR reveals the deficiency of the Protocol in terms of the gap between the principles of conservation and the means of enforcement available to implement such principles. In this respect, the CCAMLR regime, although being a resource exploitation regime, appears to be more coherent, and the institutions created by CCAMLR, despite their flaws, are essential to ensure its continuity. If the Protocol is to be implemented, there is a need to ensure a greater measure of compliance and enforcement than the rather weak CEP functions can provide. CCAMLR represents an acceptable and innovative model of institutionalization in the Antarctic context.

The institutionalization of the CEP alone will not guarantee successful implementation of the Protocol, but it will set up a framework for implementation which is dramatically lacking at present. Another prerequisite is the adoption of environmental management and monitoring tools to collect, compile and analyse environmental information. If this condition is fulfilled as well, the conservation regime established by the Protocol should then exceed that of CCAMLR in terms of innovation and efficiency.

It may be argued that state compliance with the operation of the Protocol will not depend mainly on the structure and power of institutions but rather on the political will of governments to enforce their national legislation that implements the Protocol. However, this approach alone is unlikely to produce the necessary standards of environmental protection which the Protocol describes considering the disparity between ATPs with respect to their national environmental policies and logistic involvement in Antarctica. On the contrary, this thesis argues that the institutionalisation of the CEP is a preliminary condition to a standardised implementation of the Protocol throughout

Antarctica. Indeed, providing the CEP with permanent staff and resources would secure a continuity which the CEP currently lacks. The use of GIS in such an organisational context would enhance the operational capacity of the CEP, as advocated in the following chapter regarding the development of the Antarctic protected areas system.

Chapter III:

Protected Areas Identification and Management: a proposed strategy for the implementation of Annex V of the Madrid Protocol based on information management

1. Introduction

The previous chapter examined the weaknesses of the Madrid Protocol with respect to the provisions concerning the Committee for Environmental Protection (CEP) in comparison with the role of the Commission and of the Scientific Committee of CCAMLR. Means of overcoming the institutional and decision making deficiencies of the CEP will be elaborated in this chapter which provides a strategy for implementing Annex V of the Madrid Protocol based on information management. The proposed strategy centers upon an active role of the CEP in the implementation of Annex V of the Madrid Protocol.

Annex V of the Protocol provides a regulatory framework of human activities within any area designated as an Antarctic Specially Protected Areas (ASPAs) or an Antarctic Specially Managed Areas (ASMAs). Despite the existence of such a framework, this chapter will demonstrate that the implementation of identification, designation and management procedures for protected areas raises a number of issues for the future of Antarctic scientific, logistic and tourist activities.

With the adoption of the Protocol, the Antarctic continent was declared a "natural reserve, devoted to science and peace" (Article 2) which implies that all activities within the Antarctic Treaty Area need to be managed in accordance with the provisions of the Protocol. In addition to this principle, the objectives of Annex V of the Protocol are to promote the designation of ASPAs and ASMAs, for which specific regulations apply. ASPAs are designated "to protect outstanding environmental, scientific, historic, aesthetic or wilderness value, any combination of those values, or ongoing or planned scientific research" (Article 3). ASMAs are designated "to assist in the planning and co-ordination of activities, avoid possible conflicts, improve co-operation between Parties or minimise environmental impacts" (Article 4). The regulations applying to ASMAs and ASPAs are defined in management plans which describe "management activities which are to be undertaken to protect the values for which special protection or management is required" (Article 5,c). More specifically, management plans for ASPAs need to incorporate "measures that may be necessary to ensure that the aims and objectives of the management plan can continue to be met" (Article 5,ix). The management plans for ASMAs include a code of conduct regarding "activities which are or may be conducted within the area, including restrictions on time and place" (Article 5,j(ii).

Considering the protected area system that prevailed before the adoption of the Protocol, Annex V represents a major shift from a local reservation system beyond which no environmental regulations applied, to a regional planning approach taking account of all human activities and of potential impacts upon the environment. The first focus of this chapter is to provide a legal and policy analysis of the evolution of the Antarctic protected area system, from the Agreed Measures on the Conservation of Antarctic Fauna and Flora, which were the first attempt to establish protected areas, to the adoption of the Madrid Protocol and more specifically Annex V of the Protocol, concerning Area Protection and Management. However, a comparison with the process of designation of protected areas initiated under the World Heritage Convention (strictly speaking the Convention Concerning the Protection of the World Cultural and Natural Heritage) reveals some weaknesses in Annex V; in particular, that it lacks systematically defined criteria for the designation of protected areas. This problem is examined below. In addition, the potential benefits of designating Antarctic World Heritage Sites and Antarctic Biosphere Reserves are analysed with respect to the legal and political constraints such processes would place upon Antarctic Treaty Parties.

The chapter has a second major focus. The example of the database for the management of protected areas initiated by the World Conservation Monitoring Centre raises some questions about the operation of the Antarctic protected area system with respect to information management. Uncertainties in information management and in the enforcement of standardised management procedures for Antarctic protected areas will be analysed in relation to the institutional and advisory aspects of the implementation of Annex V.

The role of the Scientific Committee on Antarctic Research (SCAR) as an advisory body on conservation issues prior to the adoption of the Protocol is examined, and the reasons for its decline analysed with respect to the new responsibilities of the CEP in the operation of the Antarctic protected area system. In order to fulfil its advisory function, the CEP needs to centralise information on the management of protected areas and to develop analytical tools for assessing the impacts of future activities within ASPAs and ASMAs.

The use of Geographic Information Systems (GIS) as a tool for the management of protected areas is discussed in the light of precedents in international organisations and existing applications of GIS at a local level in Antarctica. It will be argued that GIS could form the basis of an information strategy for regional planning and zoning in Antarctica; such a strategy is needed for the CEP in order to assess and standardise procedures and criteria of environment management in ASMAs and ASPAs.

2. Legal and Policy Aspects of the Implementation of Annex V

2.1 The evolution of the protected area system: from the Agreed Measures on the Conservation of the Antarctic Fauna and Flora to the adoption of the Madrid Protocol

The concept of protected areas applied to the terrestrial environment of Antarctica was embodied for the first time in the Agreed Measures for the Conservation of Antarctic Fauna and Flora[110]. These were adopted at the third meeting of the Antarctic Treaty Consultative Parties (ATCPs) in 1964, following a recommendation of SCAR. The Specially Protected Areas (SPAs) described in the Agreed Measures are "areas of outstanding scientific interest" which are given special protection in order to "preserve their unique natural ecological system" (Article VIII). Access to SPAs is restricted to scientific investigators authorised by permit issued for "compelling scientific purpose which can not be served elsewhere", and which will not "jeopardise the natural ecological system existing in that area". The driving of vehicles in SPAs is prohibited, along with the collection of native plants except with a permit. More generally, the Agreed Measures contain prohibitions upon the killing, wounding, capturing or molesting of any native mammal or bird (Article VI). However, harmful interference with fauna and flora is permitted within SPAs to the minimum extent necessary for the "establishment, supply, and operation of stations" (Article VII).

The Agreed Measures were originally adopted in order to give effect to the view that the Antarctic Treaty area was to be considered a special conservation area.

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[110] Agreed Measures for the Conservation of Antarctic Fauna and Flora, In: *Handbook of the Antarctic Treaty System*, 1994, Eighth Edition, U.S Department of State, pp. 2048-2056.

Their adoption required that each country should legislate, in accordance with their respective constitutional practices, to give legal effect to them. With the entry into force of the Madrid Protocol, they will become obsolete since Annex II of the Protocol on the Conservation of Antarctic Fauna and Flora incorporates the provisions listed in the Agreed Measures. As mentioned in the Handbook of the Antarctic Treaty System, "although not yet in force, Annex II to the Protocol constitutes a restatement of the Agreed Measures and will in time supersede them"[111].

(i) Environmental protection under the Agreed Measures

The adequacy of the Agreed Measures to meet contemporary concerns about environmental protection is determined by their capacity to ensure that all human activities can be accomplished with minimal impact on the environment. In this respect, the Agreed Measures, as the first attempt to implement conservation principles, were unable to solve the land use conflict between the requirements of environmental protection and the necessity for operational stations.

A good example of such a conflict is illustrated in the provisions of Article VII with respect to the case of Fildes Peninsula, King George Island. At the sixth Antarctic Treaty Consultative Meeting (ATCM), in 1966, Fildes Peninsula was given SPA status because of its "outstanding ecological interest". During the 1967-8 austral summer, the Soviet Union constructed Bellingshausen Station on the peninsula, and Chile followed by constructing Presidente Frei Montalva Station a year later. At the following ATCM, in 1968, SPA status was revoked, except for a small lake and surrounding shoreline within 100m of the water's edge at the northeast corner of the peninsula. Further degradation of the SPA led to the selection of two areas, one near the Soviet station, the other close to the Chilean one, for redesignation as Sites of Special Scientific Interest (SSSIs)[112]. As Keage notes:

While the Agreed Measures make special provision for the establishment of stations, the concentration and expansion of stations has caused severe and widespread disturbance. Under these pressures, SPAs have proved more of an inconvenience than a management tool for

[111] Handbook of the Antarctic Treaty System, op.cit, supra n° 110, p.2046.

[112] Bonner, W.N., Lewis Smith, R.I., (eds.), 1985, *Conservation Areas in the Antarctic, A review prepared by the Sub Committee on Conservation of SCAR Working Group on Biology,* Cambridge: Scott Polar Research Institute, p.144.

nature conservation.[113]

According to Article VIII of the Agreed Measures, "areas of outstanding scientific interest" shall be designated "specially protected area". The procedures for the designation of SSSIs, along with the amendment and revocation of their status, are described in Recommendation VIII-3, which was approved at the eighth ATCM following the adoption of the Agreed Measures[114]. The designation of SSSIs is applicable to "areas of exceptional scientific interest" which "require long-term protection from harmful interference"[115]. The purpose of such designation is therefore to safeguard research opportunities and to prevent human interference to sites. SSSIs are designated for a fixed period and are kept under review by SCAR[116]; a permit is not required to access the sites as is the case with SPAs[117].

The procedures for the designation of SPAs and SSSIs, along with the amendment and revocation of their status, show a division of competence between the advisory role of SCAR and the decision power of Consultative Parties which undermines the purposes of conservation[118].

On one hand, SCAR is invited to propose the designation of sites worthy of protection to ATCMs. This process of designation involves expedition personnel suggesting sites of scientific and/or ecological importance to their national scientific committee of SCAR. But, according to Recommendation VIII-3 paragraph 1a(i), sites should only be proposed when "there is a demonstrable risk of interference which would jeopardise those scientific investigations"; or paragraph 1a(ii) when "sites are of exceptional scientific interest and therefore require long-term protection from harmful interference". Submissions are reviewed by national committees. Finally, SCAR is responsible for proposing to ATCMs areas for special protection. On the other hand, Consultative Parties are allowed by Article XIV of the Agreed Measures to adopt sites for special

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[113] Keage, P.L., 1986, *Antarctic Protected Areas: Future Options*, Environmental Studies Occasional Paper 19, Centre for Environmental Studies, University of Tasmania, Hobart, Tas., p.45.

[114] Recommendation VIII-3, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 110, pp.2088-2089.

[115] Recommendation VIII-3, paragraph 1a(ii).

[116] Recommendation VIII-3, paragraph 1(b) and 2.

[117] Agreed Measures, Article VIII 2(c), 3 and 4.

[118] For comments about these procedures, see Bonner and Lewis-Smith, op.cit, supra n° 112; and Keage, op.cit, supra n° 113.

protection, or amend or revoke their status by unanimous agreement. The possible revocation of protected area status consequently subordinates environmental protection to logistical priorities imposed by the establishment and operation of stations. Such priorities are defined at the political level of ATCMs where Consultative Parties have a discretionary power of decision.

(ii) Limitations of the Agreed Measures in environmental management

At the seventh ATCM, it was decided that the number of protected sites should be kept to the minimum required and for sites to be as small in area as was necessary to meet the purpose(s) for which they have been designated. Such restrictions upon the size and number of protected areas seem incompatible with the increase of human activities during that period, when accession to the status of Consultative Party required, for each country, the establishment of a station in Antarctica; nonetheless this decision was maintained despite the fact that, in 1968, SCAR's Working Group on Biology recognised the need to increase the areas of protected sites. In addition, the absence of criteria for designation of protected areas in order to ensure the representativeness of Antarctic ecosystems led to sporadic designations. As Keage notes:

> Existing sites are not fully representative of Antarctic ecosystems. A network of representative sites can only be formulated from an inventory of habitat and ecosystem types, which gives their relative abundance, distribution and geographical area. This would allow protected sites to be established on a biogeographical basis with several representative examples in each biogeographic province[119].

Two positive steps for Antarctic conservation were taken with the designation of SSSIs: first of all, whereas SPAs were only applicable to biological sites, the scope of protection was now extended to geological areas of scientific interest since the need to protect scientific investigations irrespective of their purpose has been recognized in Recommendation VIII-3; and secondly, a management plan is required for SSSIs, which includes a description of the site, and an outline of research and of restraints which may be needed[120]. The requirement of a management plan coincides with the recognition of the need to set restrictions in place in order to avoid interference with the objectives of SSSIs designation. As mentioned above in the case of Fildes Peninsula, the need for

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[119] Keage, op.cit, supra n° 113, p.46.

[120] Recommendation VIII-3, paragraph 1(c).

restrictions was denied at first for the SPAs. Indeed, the absence of a management and monitoring scheme for SPAs under the Agreed Measures increases the vulnerability of sites which are likely to be subject to human impacts, as in the case of Cape Hallett SPA, and this raises the question of the usefulness of SPA designation in the absence of such a scheme. In 1966, a small area of Cape Hallett was designated a SPA because of its diverse vegetation, which supports terrestrial fauna and rich avifauna of outstanding scientific interest. However, prior to its designation the site of the Cape Hallett SPA was subject to a decade of disturbance from Hallett Station, which operated from 1956 to 1965. Disturbance to breeding birds was caused by station construction and such activities as site levelling, roadworks, blastings and snow-drifts formed by constructions which permanently cover land that was previously ice-free and colonised by breeding birds. In 1984 a programme to dismantle the station began and it is planned to restore the site to its original condition as far as possible[121]. Despite the outstanding vegetation and fauna present at Cape Hallett, it can be argued that its designation as an SPA was inappropriate, because of the extent of human impacts in the area. As Keage notes, "human impact on the local environment at Cape Hallett was greater than at most stations and its most important contribution may be as a SSSI for scientific studies of human interactions with the polar environment"[122].

(iii) Towards active management: the introduction of management plans

Improvements were made in 1987, when SCAR recommended that a management plan be prepared for each existing and all future SPAs. At the fifteenth ATCM, two recommendations were adopted: Recommendation XV-8, which allowed for the insertion of a management plan within the description of an SPA in Article VIII of the Agreed Measures[123]; and Recommendation XV-9, which further describe the required content of management plans for SPAs[124]. Recommendation XV-9 para.2 (d) included a "description of the types of activities (including activities outside the area) that could jeopardise any of the components of the unique ecological system intended to be preserved"; whilst para. 2(f) required the provision of "a description of measures necessary to

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[121] Bonner, W.N., and Lewis Smith, R.I., op.cit, supra n° 112, p.44.

[122] Keage, P.L., op.cit, supra n° 113, p.42.

[123] Recommendation XV-8, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 110, p.2106.

[124] Recommendation XV-9, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 110, p.2106-2107.

ensure preservation of the area's unique or representative natural ecological system". As Bonner remarks, this final sub-paragraph opens the door for policies of "active management" through "a clear definition of the objective to be achieved by protection. Once the objective has been decided, it is possible to design a programme of activities to achieve this. These activities constitute what is more generally considered as active management"[125].

Recommendation XV-9 does not contain any reference to the objective sought in designating protected areas. However, this gap is now filled with Annex V of the Protocol which provides a legal mechanism for active management. Article 5.3(b), states that each designated area shall have a management plan containing "a statement of the aims and objectives for the protection or management of those values [for which special protection or management is required]". In paragraph 3 (i) (ix) of Article 5, the granting of permits authorises "measures that may be necessary to ensure that the aims and objectives of the management plan can continue to be met".

In contrast to the new framework of Annex V, the inadequacy of the passive management that prevailed under the Agreed Measures is described by Bonner as follows:

> Passive management, based solely on restrictive measures, is now widely recognised as inadequate for fulfilling all the objectives of conservation. Taking active steps, so as deliberately to prevent or reverse change on the area protected, is seen as essential in many cases. Passive management was the type of management provided under the Antarctic Treaty by the Agreed Measures for the Conservation of Antarctic Fauna and Flora for Specially Protected Areas (and to a large extent, to the Antarctic Treaty Area generally)[126].

(iv) The Madrid Protocol: introducing a regional planning approach to conservation

With the Protocol, the shift from passive to active management of protected areas is reinforced in Annex V by the creation of the ASMA mechanism which incorporates a regional planning approach to conservation, instead of protected

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[125] Bonner, W.N., 1994, Active Management of Protected Areas, In: (Lewis-Smith, R.I., Walton, D.H.W., and Dingwall, P.R., eds.),1994, *Developing the Antarctic Protected Area System, Proceedings of the SCAR/IUCN Workshop on Antarctic Protected Areas, 29 June - 2 July 1992*, Gland and Cambridge: IUCN, p.62.

[126] Bonner, W.N., op.cit, supra n° 125, p.61.

areas based on small site specific values, outside of which no regulations apply. Indeed, the ASMA mechanism provides scope for a zoning system which would integrate different areas according to their degree of sensitivity to human activities, by defining, for example, buffer zones around ASPAs located in proximity to station operations. Article 5(3)f of Annex V refers to management plans which shall include "the identification of zones within the area, in which activities are to be prohibited, restricted or managed for the purpose of achieving the aims and objectives referred to in sub-paragraph (b) above".

The scope of ASPAs is also extended within the Protocol to "areas of outstanding aesthetic and wilderness value" (Article 3(2)g). This represents a considerable adjustment to the conservation values, defined by IUCN as follows:

Conservation in Antarctica is now recognised as important not least because of the aesthetic value of a great wilderness, largely free from human pressure, in an overpopulated world. The protection of the unique Antarctic environment and ecosystems, as a distinctive component of planetary biological diversity, has become a major focus of attention for people throughout the world[127].

However, the question of the identification and selection of "areas of outstanding aesthetic and wilderness value" remains linked to the designation process for protected areas described in Annex V.

With respect to the absence of criteria for the designation of protected areas that prevailed under the Agreed Measures, Article 3(2) of Annex V refers to "a systematic environmental-geographical framework" that Parties shall seek to identify and to include in the series of ASPAs.

Despite the adoption of matrices by SCAR to classify Antarctic ecosystems, the representativeness of the ecosystem types has been unevenly achieved. According to Kriwoken and Keage, "the terrestrial, freshwater and inshore marine ecosystems are under-represented or totally absent in the protected areas classified according to the existing SCAR matrices, while littoral and inland fluvial and continental ice systems are absent"[128].

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[127] IUCN, 1991, *A Strategy for Antarctic Conservation,* Gland and Cambridge: IUCN, p.1.

[128] Kriwoken, L.K., and Keage, P.L., 1994, Identification and selection of protected areas, In: Smith, Walton and Dingwall, op.cit, supra n° 125, p.38.

In order to improve the representativeness of ecosystems in the designation process of protected areas, it seems necessary to establish more specific criteria for their identification and selection, that all Parties would then need to apply. At present, the identification and selection of protected areas remain subject to the different interpretations made by Treaty Parties. As Kriwoken and Keage note:

The adoption of concepts, and their modification for use in Antarctica, is additionally complicated by national/cultural interpretations of site identification and selection criteria. Thus, each Antarctic Treaty Consultative Party continues to conduct its environmental affairs within the context of its own standards (and margins) of acceptability. The need to better define environmental standards and criteria, including those of protected area identification and selection, is a matter deserving closer attention[129].

In this respect, lessons can be drawn for the operation of the Antarctic protected area system by comparing past practice with the process of designation of protected areas initiated by international organisations external to the ATS.

2.2 A comparison between the mechanisms of Annex V and the process of designation for protected areas initiated by international organisations external to the Antarctic Treaty System

This section will first of all demonstrate the practical benefits to be gained from the application to Antarctic protected areas of the mechanisms for site identification and site management initiated under the World Heritage Convention[130] and the Man and Biosphere Programme of the United Nations Educational, Scientific and Cultural Organisation (UNESCO)[131].

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[129] Kriwoken, L.K., and Keage, P.L., op.cit, supra n° 125, p.40.

[130] Convention concerning the Protection of the World Cultural and Natural Heritage, *International Legal Materials*, 11: 1358 (November 1972).

[131] UNESCO-UNEP, 1974, *Final Report: Programme on Man and Biosphere (MAB) Task Force on: Criteria and Guidelines for the Choice and Establishment of Biosphere Reserves*, MAB report series n° 22, Internatioanl Co-ordinating Council of the Programme on Man and the Biosphere, Paris: United Nations Educational, Scientific and Cultural Organisation, 61 pp.

As mentioned before, the requirement of representativeness of ecosystems in protected area designation is only defined in loose terms in Article 3.2(b) of Annex V, which refers to "representative examples of major terrestrial, including glacial and aquatic ecosystems and marine ecosystems" that Parties shall seek to identify. However, Annex V does not elaborate a methodology for implementing "a systematic environmental-geographical framework"[132] which would ensure the representativeness of ecosystem types. As Keage notes:

> There is no strategy to ensure that protected areas are classified into biogeographical provinces, or that for each province there are a number of protected ecosystem types for replication. Instead, existing protected areas are neither representative of Antarctic ecosystems generally or evenly distributed biogeographically[133].

This observation, though made before the adoption of the Protocol, emphasizes the current need to define criteria of representativeness for Antarctic ecosystem types in order to complete the "systematic environmental-geographical framework" to be used for the identification of Antarctic protected areas described in Annex V[134]. In this context, mechanisms for ensuring representativeness of ecosystems for protected areas created by international organisations outside the ATS are examined below to ascertain their suitability for the identification of Antarctic protected areas.

(i) The option of recourse to the World Heritage Convention for ensuring representativeness of ecosystem types

Lucas defines representativeness as "a goal in the selection of protected areas to maintain the fullest possible range of natural ecosystems and, with them, biological diversity". He also notes that "IUCN's approach to representativeness with protected natural areas has been to adopt and encourage a systematic approach and the World Conservation Strategy identified the need for each country to protect 'a complete range of ecosystems representative of the different types of ecosystem' in that country"[135]. This approach has been followed by the World Heritage Convention, under the auspices of UNESCO, for the identification of World Heritage Sites.

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[132] See Article 3.2 of Annex V.

[133] Keage, P.L., op.cit, supra n° 113, p.31.

[134] Chapter V of this thesis provides an interpretation of representativeness and a methodology for identifying representative areas within the Windmill Islands region.

[135] Lucas, P.H.C., 1992, *Protected Landscapes*, London: Chapman & Hall, p.45.

With respect to site identification, the application of the World Heritage Convention to Antarctic sites represents a potential option for ensuring representation of "areas of outstanding aesthetic and wilderness value" which were added to the rationale for selecting protected areas in Article 3(2)g of Annex V. Indeed, the Dry Valleys of Victoria Land and the Transantarctic Mountains, along with the shores of McMurdo Sound with their historical relics of early twentieth century exploration, are examples of areas previously mentioned in the literature for World Heritage Listing[136].

In conservation terms, Antarctic World Heritage Sites would guarantee additional environmental protection, moderating the conflicting land-uses that might otherwise jeopardise the natural qualities which would be the basis for area designations, as Keage illustrates in the case of the Dry Valleys:

> In 1969 and 1976, SCAR called for SPA proposals to be drafted for the Dry Valleys. The Dry Valley drilling programme which started in the early 1970s had a major environmental impact when drilling fluids leaked from drill casings; drilling fluids were pumped into a major lake. these incidents occurred despite rigorous environmental impact assessment in the early stages of programme planning. Lake Bonney remains the only major lake in the region not to have been contaminated to some degree by geological drilling. At ATCM VIII, a site in the Barwick Valley (300 km2) was declared a SSSI. In 1976, the SCAR working group on Biology recommended that Lake Bonney in the Dry Valleys be declared a SSSI, and that existing protected site boundaries be extended, particularly for inland and marine areas vulnerable to disturbance, but no action has yet been taken in relation to the region or its coastline[137].

Recently, concerns about the long-term cumulative impacts of scientific studies and increasing tourist activities in the Dry Valleys region led to a meeting of international specialists held in Santa Fe, New Mexico, in March 1995. One important outcome of this workshop was to develop a framework for a management plan that would establish management zones based on a matrix of sensitivity to impact and the nature of disturbances. The proposed management plan would rely upon GIS technologies by incorporating major landscape elements, biological communities and evidence of environmental change. As Vincent[138] notes, this zoning and the associated monitoring regime should be

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[136] IUCN, op.cit, supra n° 127, p.53.

[137] Keage, P.L., op.cit, supra n° 113, p.32.

[138] Vincent, W.F., (ed.), 1996, Environmental Management of a Cold Desert Ecosystem: the Mc Murdo Dry Valleys, Desert Research Institute, University of Nevada, special publication, 57 pp.

closely tied to requirements under the Madrid Protocol.

It may be argued that the guarantee of environmental protection given by the World Heritage Convention is no longer required with the ASPA and ASMA mechanisms introduced in Annex V. However the incorporation of existing and future ASPAs into the network of World Heritage Sites would increase the accountability of ATPs to the internationally accepted criteria for site identification and site management of protected areas existing in the rest of the world. In doing so, ATPs would be able to prove that Annex V of the Protocol is being effectively implemented. As Holdgate notes:

> It would be most desirable for the designation of areas of environment subject to various protection regimes in Antarctica to proceed on a basis, and using terms, as close as possible to those adopted in other regions of the world. Such an approach not only helps establish genuine compatibility and comparability, but will help in the wider process of reassuring the world community that the Antarctic environment, which some regard as 'a global common', is being safeguarded appropriately[139].

However, the political and legal characteristics of the designation process of World Heritage Sites seem to preclude a direct application of the World Heritage Convention in Antarctica since designations depend on the exercise of unchallenged sovereignty. The World Heritage Convention includes 110 countries as State Parties and became operational in 1978 with the creation of a secretariat and a committee. The designation process for World Heritage Sites is initiated by State Parties to the Convention who submit proposals to the World Heritage Secretariat[140]. The World Heritage Committee, whose members are elected by State Parties[141], draws operational guidelines for the implementation of the World Heritage Convention, containing criteria against which proposals are evaluated[142]. The Committee also makes decisions on requests for support from the World Heritage Fund [143].

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[139] Holdgate, M.W., 1994, International Designations, In: Lewis-Smith, R. I., Walton, D. H. W., and Dingwall, P. R., op.cit, supra n° 125, p.104.

[140] Article 3 and 4 of the Convention for the Protection of World Cultural and Natural Heritage, op.cit, supra n° 130.

[141] Article 8 of the Convention for the Protection of World Cultural and Natural Heritage, op.cit, supra n° 130.

[142] Article 11(5) of the Convention for the Protection of World Cultural and Natural Heritage, op.cit, supra n° 130.

[143] Articles 15 and 16 of the Convention for the Protection of World Cultural and Natural

In contrast with the designation process of Antarctic protected areas described in Annex V, the World Heritage Convention has established an objective procedure, including criteria for assessment of nominated sites. In addition to this, once a site is listed, the responsible state has an obligation for maintenance, management, monitoring and the supply of information regarding the condition of the site, which can be questioned by the World Heritage Committee. Such scrutiny placed upon ATPs, if the World Heritage Convention was applied to Antarctic sites, seems politically incompatible with the exercise of sovereignty. Article 4 of the Antarctic Treaty froze all territorial claims, which thus precludes the direct jurisdiction over the areas that would be required under the World Heritage Convention. As the Australian Antarctic Foundation has noted, "the unilateral nomination of an area for World Heritage status would be regarded as prejudicial to the accommodation of sovereignty under the Treaty and, in its present form, the World Heritage Convention cannot be applied to the Treaty area"[144].

(ii) The option of recourse to the Biosphere Reserve concept for ensuring representativeness of ecosystem types

The application to Antarctic protected areas of the Biosphere Reserve concept, initiated under the Man and Biosphere (MAB) Programme of UNESCO, does not fall foul of the political and legal obstacles outlined above with regard to the designation of Antarctic World Heritage Sites. As Holdgate notes:

> The establishment of Antarctic Biosphere Reserves appears possible using mechanisms compatible with those adopted for other continents, especially since the Biosphere Reserves are not established under a specific Convention or Treaty. Many existing protected sites could well be brought within the compass of such reserves[145].

For example, Macquarie Island, in the Sub-Antarctic region, was designated a Biosphere Reserve by Australia in 1977.

Moreover, the Biosphere Reserve concept emphasises a systematic international network of protected areas based on "representative ecosystems" rather than

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Heritage, op.cit, supra n° 130.

144 Australian Antarctic Foundation, *A Conservation Strategy for the Australian Antarctic Territory*, Draft 13 October 1993, p.12.

145 Holdgate, M.W., op.cit, supra n° 125, p.104.

exceptional ones, which is the case with World Heritage Sites. It thus coincides with the approach described in Article 3(2) of Annex V.

The meaning of "representative ecosystems" was clarified, firstly, at the request of UNESCO and IUCN, by the elaboration of a comprehensive classification of the different ecosystem types within the world. This classification was based upon the concept of biogeographical provinces defined according to faunistic and floristic differences and vegetation structures. For instance, Udvardy identifies "193 biogeographical provinces belonging to 14 types of biome within 8 biogeographic realms"[146]. This approach enabled the Man and Biosphere Bureau to set up at least one biosphere reserve in each biogeographical province, as a priority objective of designation.

There is a difficulty however, as Batisse notes:

> As Biosphere Reserves are proposed upon the initiative of individual countries, their designation could not be made in a systematic manner but has been rather haphazard. It is therefore not surprising that, out of the 193 biogeographical provinces of the Udvardy classification, only 91 are represented today in the network by one or more Biosphere Reserves[147].

In this respect, there would be mutual benefits derived from the application of the Biosphere Reserve concept to Antarctic protected areas. Firstly, it would enhance the representativeness of Antarctic ecosystems within the Biosphere Reserve network. Secondly, it would complete the definition of a "systematic environmental-geographical framework" that ATPs need to adopt in the identification of protected areas.

Moreover, the Biosphere Reserve concept embodies innovative planning and management principles based on zonation which could be used for the implementation of the ASMA mechanism described in Article 4 of Annex V. As Batisse states:

> The idea is that the reserve should normally include a protected 'core area' surrounded by one or several 'buffer areas' allowing for manipulative research or traditional land-use, and acting

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[146] Udvardy, M.D.F., 1975, *A Classification of the Biogeographical Provinces of the World,* IUCN Occasional Paper n° 1196, Gland: IUCN.

[147] Batisse, M., 1982, The Biosphere Reserve: a Tool for Environmental Conservation and Management, *Environmental Conservation,* volume 9, n°2, p.106.

as a transition zone ensuring proper integration of the reserve into the geographic region which it represents and actually serves. The 'core area' should be representative of a major ecosystem of world significance, and be large enough to allow for *in situ* conservation of the genetic material of this ecosystem. The area thus devoted essentially to conservation would usually receive minimal human interference, and would serve as a baseline for monitoring changes occurring in the Biosphere as well as for research of a non-destructive character. A 'first buffer-zone' around the core area would be used for education and training, as well as for manipulative research on conservation and ecosystem management. When possible a second or 'outer buffer-zone' is recognised, which then serves a variety of purposes, including experimentation on alternative land-uses, education, training and recreation[148].

In the Antarctic context, the "core area" would correspond to existing and future ASPAs, as strictly protected areas or areas safeguarded for scientific research, surrounded by a "first buffer zone" allowing tourist and recreation activities, and an "outer buffer zone" within which station activities would be contained, corresponding to ASMAs. Furthermore, the Biosphere Reserve concept, emphasizing environmental monitoring and research, would coincide with the scientific focus of current Antarctic activities.

Indeed, the zonation system prescribed by Harris for Specially Protected and Managed Areas under the Protocol contains similarities with the model elaborated for Biosphere Reserves. Harris proposes "a standardised model of five types of zones: Restricted, Scientific, Tourist, Facilities and Historic"[149]. The zoning approach has thus been institutionalised. In the new requirements for management plans set out in Annex V, designation is required for particular land-use and activity planning within ASPAs and ASMAs. The Restricted Zone described by Harris for ASMAs and ASPAs aims "to restrict or prohibit access into a particular part of the ASPA or ASMA for a range of management or scientific reasons"[150]. The Scientific Zone within the ASPA is "to ensure those who enter the ASPA are aware of the areas within that are sites of current scientific investigation"[151]; within the ASMA the Scientific Zone is "to protect small-scale, transient scientific projects from accidental or mutual interference". The Tourist Zone within an ASPA is "to ensure tourists who enter the ASPA are aware of the areas within which they are to be restricted"; within an ASMA the

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148 ibid., p.102.

149 Harris, C.M., 1994, Standardisation of Zones within Specially Protected and Managed Areas under the Antarctic Environmental Protocol, *Polar Record,* volume 30, n°175, pp. 283-286.

150 ibid., p.285.

151 ibid., p.285.

Tourist Zone is "to provide a means of managing the activities of tourists so their impacts may be monitored and contained". The Facilities Zone within an ASMA is "to contain stations and facilities within pre-defined areas and provide means to control their spread". The Historic Zone within an ASMA is "to recognise, protect and manage historic sites of local or regional significance"[152]. A transposition of the Restricted and Scientific Zones described by Harris to the zonation model for Biosphere Reserves would integrate these two zones within the "core area", while the Tourist and Historical Zones would coincide with the "first buffer zone". The Facilities Zone would represent the "outer buffer zone" of the Biosphere Reserve. There would not be any incompatibility in implementing both zonation models, for they are fully complementary in their respective attempts to fulfil the requirements of conservation along with environmental management and planning needs in Antarctica. As Holdgate notes: "All sites designated as ASPAs with biological conservation as their objective could be considered as Biosphere Reserves"[153].

(iii) A Protected Area Database: a Precedent from Biosphere Reserves and World Heritage Sites

Another possible development for Antarctic protected areas is the inclusion of sites on the United Nations List of National Parks and Protected Areas published by IUCN. As Holdgate notes, "IUCN maintains a register of Threatened Protected Areas of the world and the inclusion of sites in such a list can often stimulate remedial action by the government or authority concerned"[154]. The Protected Areas Data Unit (PADU) was inaugurated in 1981, as part of the IUCN's World Conservation Monitoring Centre (WCMC), in response to the needs of the MAB Programme and of the World Heritage Convention with respect to global information on protected areas. Such information is crucial, on one hand, to ensure that representative areas of all biogeographical provinces are established as Biosphere Reserves and, on the other hand, to ensure that sites nominated to the World Heritage List are of "truly universal significance". Indeed, IUCN's Commission on National Parks and Protected Areas (CNPPA) is responsible for the technical evaluation of sites recommended for inclusion on the World Heritage List; PADU is the original database where information on these sites is maintained. The work of PADU has been described by Harrison:

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152 ibid., p.285.

153 Holdgate, op.cit, supra n° 139, p.103.

154 ibid., p.100.

International agencies would be able to design their projects to enhance sustainable development and to avoid adversely affecting sensitive areas if they could be provided with quick, large-scale 'overviews' of certain questions concerning protected areas, and with details of the protected areas of the region in which they are working[155].

In 1989, the WCMC initiated work on the world's ecosystems in response to a need to supply information on the habitats on which threatened species depend for their survival. This led to the creation of a Protected Areas Map Database linked to the main WCMC Protected Areas Database and using GIS techniques.

The main benefit to be gained from the inclusion of Antarctic protected areas in the United Nations List of National Parks and Protected Areas of the WCMC Protected Areas Database would be to fill the current gap in the data management of protected areas within the ATS. On the other hand, the new provisions of the Protocol defining ASPAs and ASMAs would have to fit in these categories, which is currently not systematically the case. At present, the only Antarctic sites included in the WCMC Protected Areas Database are those covering more than 1,000 ha and meeting the strict criteria of the IUCN Management Categories I-V, such as category I corresponding to the strict nature reserve/scientific reserve[156]. In this context, the creation of a regional database for Antarctic protected areas would be more appropriate in terms of providing the elements of comparability necessary to ensure a standardised management of protected areas. Such a database would follow the compilation of information on Antarctic protected sites established by Bonner and Smith in 1985 [157].

There is currently no institution responsible for the centralisation and management of data for Antarctic protected areas, which is crucial to site identification and management as well as environmental monitoring. The example of PADU demonstrates that the creation of a database is essential to the establishment of Biosphere Reserves and World Heritage Sites. Similarly, information management with respect to Antarctic protected areas is an issue

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155 Harrison, J., 1983, Maintaining a Database on the World's Protected Areas, *Parks*, volume 7, n°4, p.3.

156 A list of the Antarctic sites included in the WCMC Protected Area Database is available on Internet: http://w.w.w.wcmc.org.uk/, World Conservation Monitoring Centre Web Server, U.K.

157 Bonner, W.N, and Lewis-Smith, R.I., op.cit, supra n° 112.

that needs to be urgently addressed since it is likely to otherwise jeopardise the implementation of Annex V. Article 12 of the Protocol includes, among the functions of the CEP, the provision of advice on: "(i) the collection, archiving, exchange and evaluation of information related to environmental protection"; and (k) "the need for scientific research, including environmental monitoring, related to the implementation of this Protocol". This provision gives scope to the extension of the institutional and advisory capacity of the CEP with respect to the information management of Antarctic protected areas, and it is to this we turn in the second part of this chapter.

3. Institutional and advisory aspects of the implementation of Annex V

Analysis of the institutional and advisory aspects of the implementation of Annex V requires, first of all, an examination of the role of SCAR in the Antarctic protected area system, and of the reasons for its decline as an advisory body within the ATS. The potential conflicts between SCAR and the CEP when exercising their advisory functions as described in the Protocol will then be outlined in order to demonstrate the need for strengthening the role of the CEP with respect to the implementation of Annex V. This will underpin a proposal for an information management scheme for Antarctic protected areas in which the CEP will play a central role.

3.1 The evolving role of SCAR in the Antarctic protected area system

The evolution of SCAR within the ATS is characterised by a dual role as a coordinating body for Antarctic science and as an advisory body to ATCMs, presenting some limitations in the context of the new requirements of the Protocol.

Historically SCAR was established as a continuation of a special committee on Antarctic research whose task was to oversee and coordinate research during the International Geophysical Year. The membership of SCAR therefore includes the national committees of scientific academies and research councils involved in Antarctic research, and initially its main purpose was to provide a forum for scientists to discuss field activities and promote mutual collaboration. To do this, SCAR's meetings are held every other year and it has a secretariat located at the Scott Polar Research Institute in Cambridge, England.

However, with the adoption in 1964 of the Agreed Measures on the Conservation of the Antarctic Fauna and Flora, which were based on conservationist principles developed by SCAR, the importance of the advisory role of SCAR within the ATS started to increase. Recommendation VII-2 invited SCAR to review existing and proposed SPAs[158]. Following this recommendation, the Sub-Committee on Conservation of the SCAR Working Group on Biology produced the first compilation of information on protected sites. Recommendation XII-3 asked for SCAR's advice on the categories of scientific and logistic activity that might have a significant effect on the Antarctic environment[159]. Consequently, SCAR elaborated a procedure for evaluating impacts from scientific and logistic activities which led to the adoption of a recommendation on Environmental Impact Assessment (EIA) at the XIV ATCM. During the 1980s, in response to growing concerns about environmental protection, SCAR restructured its working groups and in 1988 created the Group of Specialists on Environmental and Antarctic Conservation (GOSEAC).

(i) The need for a review of the advisory functions of SCAR

Despite these considerable efforts to respond to requests for advice, it is now recognised that the current structure of SCAR does not allow it to carry out its advisory functions without prejudicing its pre-existing scientific responsibilities. The conflict between the scientific and advisory agenda of SCAR thus required a review of its functions within the ATS.

One important conclusion from the report of SCAR's review, presented at the 30th meeting of the International Council of Scientific Unions (ICSU) General Committee held in Jerusalem in November 1992, was that SCAR should be encouraged to give first priority to science. As chairman of the panel of experts appointed to undertake the review of SCAR, Coldwell reported:

> The nature of SCAR is one reacting to need, rather than developing a vision of the future and this has become a problem. Many research scientists are asking SCAR to be more proactive and to develop other institutional arrangements which can better deal with current needs and pressures. SCAR's activity in the science policy advisory arena has been somewhat reduced in the last few years, since a number of other bodies serve this function within the Antarctic Treaty Organization. Consequently, SCAR might consider greater concentration on science and less on

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[158] Recommendation VII-2, In: Handbook of the Antarctic Treaty System, op.cit, supra n° 111, p.2086.

[159] Recommendation XII-3, In: Handbook of the Antarctic Treaty System, op.cit, supra n° 111, p.2032.

science advisory functions[160].

Moreover, the advisory capacity of SCAR seems to be inhibited by its current structure and by the difficulty of gaining support for its recommendations in the intensely political arena of the ATCMs. This situation is exacerbated by a lack of resources: with an annual budget of US $200,000-300,000 per year[161], SCAR cannnot respond effectively to all requests for advice that come along. As Bonner notes, "SCAR currently has been unable to provide properly considered advice on questions relating to protected areas and environmental monitoring because it has not been possible to find the funding for meetings on these subjects"[162]. In addition to this, the composition of SCAR promotes a lack of unity in the formulation of scientific advice, and this undermines its role as an independent body. As Barnes notes:

> SCAR is not a body that implements decisions on an international arena. It is only a body that works through National Academies and the like, which means that variations in national policies make it improbable that SCAR can act in the united way one might like to see; this is especially the case when it comes to issues involving politically sensitive questions[163].

But there is more to the problem than financial resources. The subordination of SCAR's recommendations to political priorities defined at ATCMs reinforces the limitations of its advisory capacity. In this respect, the division of responsibilities between SCAR (via its National Committees), which identifies prospective protected areas, and individual ATCPs which select and manage them, illustrates the gap existing between the formulation of advice and decision making. As Kriwoken and Keage note: "ATCPs are empowered to select protected areas and implement management arrangements: they can seek specialist advice from SCAR when required but need not accept such advice"[164].

In addition to these limitations upon the advisory capacity of SCAR, the creation of the CEP following the adoption of the Protocol and the setting up of

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[160] Coldwell, R.R., 1992, Some views on Antarctic research, In: (Elzinga, A., ed.), *Changing Trends in Antarctic Research,* Dordrecht: Kluwer Academic Publishers, p.146.

[161] Source: Coldwell, R.R, op.cit, supra n° 160, p.146.

[162] Bonner, N.W.,1992, The Science/Politics Interface in Development; In: (Elzinga, A., ed.) op.cit, supra n° 160, pp.109-110.

[163] Barnes, J., 1992, The Place of Science in an Environmentally Regulated Continent, In: (Elzinga, A., ed.) op.cit, supra n°160, p.64.

[164] Kriwoken, L.K., and Keage, P.L., op.cit, supra n° 128, p.39.

environmental monitoring programs constitute additional constraints placed upon SCAR, and the two main reasons for its decline as an advisory body within the ATS.

(ii) Implications of the Protocol's new focus on environmental monitoring for SCAR's activities

The Protocol calls under Article 3.2(d) and Article 3.2(e) for regular and effective monitoring to allow assessment of the impacts of ongoing activities, including the verification of predicted impacts, as well as to facilitate early detection of the possible unforeseen effects of activities on the Antarctic environment. The same issue is addressed in ATCM recommendation XV-5 which specifies monitoring programs relevant to activities such as: "(d) conduct of science programs; and (f) those affecting the purposes of designated protected areas", which are of particular importance for the implementation of Annex V of the Protocol.

Following this recommendation, SCAR and the Council of Managers of Antarctic Programmes (COMNAP) put out a discussion document in which a distinction is made between basic research monitoring and applied monitoring to assess the impacts of activities. This distinction is of particular relevance for the analysis of the new constraints environmental monitoring is placing upon SCAR's activities:

> The first type of monitoring, i.e. basic research monitoring, is a normal part of ongoing scientific programmes in Antarctica and as such is given considerable attention and support. For practical purposes, however, it is often necessary to do monitoring of a more direct applied nature. This second type of monitoring, i.e. applied operations environmental impact monitoring, does not have the same scientific tradition. Applied monitoring, driven by practical needs and not the advancement of scientific understanding, is a new field for most Antarctic operators. Since this activity falls outside the scientific career and funding system, it is important to recognise the full organizational and resource implications of any applied monitoring programmes.[165]

Thus the new focus on environmental monitoring introduced by the Protocol is quite significant so far as SCAR's activities are concerned. On one hand, it represents a major shift from basic research toward monitoring in order to provide the scientific evidence required for adequate decision making. For this,

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[165] *Environmental Monitoring in Antarctica*, 1992, a discussion document prepared by SCAR and COMNAP, March 1992, Unpublished, 23 pp.

a more global and integrated approach to international research is needed, which does reinforce SCAR's initial role in the co-ordination of Antarctic science. On the other hand, with science having been identified as a contributor to localized environmental impacts, increased scrutiny is now placed upon scientific programs with the setting up of applied operations environmental impact monitoring. As Coldwell notes, "additional pressure on the conduct of relevant Antarctic science, and on SCAR, results from the complexity and interrelationships in large national systems that are involved in Antarctic research. Thus, strong coordination and effective international cooperation is required for modern, large scale, and sophisticated programs"[166].

Moreover, applied environmental monitoring programs and basic research have distinctive goals, the latter being devoted first and foremost to the advancement of science. It is the role of SCAR to encourage basic research in the context of changing trends in Antarctic science. Given this, some scientists are in favour of a retreat by SCAR from its advisory role in order to focus on the promotion of science. This attitude is reflected in the report of the review of SCAR held in 1992.[167]

Under the new regime established by the Protocol SCAR will be sharing its advisory functions with the CEP, which is to provide advice on "the need for scientific research, including monitoring, related to the implementation of this Protocol", as stated in Article 12.1(k). However, the way this new advisory process is to operate in practice is not clearly defined by the Protocol. Article 12.2 of the Prtocol merely stipulates that, "in carrying out its functions, the CEP shall as appropriate consult with SCAR, the Scientific Committee of CCAMLR, and other relevant scientific, environmental and technical organizations". One interpretation of this provision is that the CEP would become the main advisory body and would consult with SCAR for scientific advice, respecting SCAR's experience in Antarctic conservation. As Bonner argues:

> A legal mechanism for protecting the environment will work only if it is based on sound scientific advice. Where the Antarctic is concerned, SCAR is the organisation that can provide the best access to such advice. SCAR uniquely embodies the individuals with practical experience in Antarctic conditions of carrying out scientific research programmes under these conditions[168].

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[166] Coldwell, R.R., op.cit, supra n° 160, p.147.

[167] ibid.

[168] Bonner, N.W., op.cit, supra n° 162, p.108.

From this point of view, it seems inappropriate for the CEP to replace SCAR as advisor to the ATS on the scientific aspects of environmental protection. At the same time, the current structure of SCAR denies it the capacity to provide advice on all matters related to environmental protection, especially with respect to environmental management in Antarctic protected areas. This task clearly falls under the CEP competence.

Having earlier analysed the limitations of SCAR as an advisory body, lessons can now be drawn for the operation of the CEP. In order to avoid the same shortcomings, it is essential to strenghten the advisory capacity of the CEP and to provide it with environmental management tools such as GIS, which will be discussed in the following section.

3.2 The need for strengthening the advisory capacity of the CEP

This section will focus on the use of GIS as a management tool which would strengthen the advisory capacity of the CEP in the implementation of the protected area system described in Annex V. The argument will first be supported by precedents from international organisations and from local applications of GIS in Antarctica. The applicability of GIS as part of an information management strategy for protected areas will then be demonstrated.

Once created, the CEP will become the main body responsible for monitoring Antarctic protected sites according to a number of provisions contained in the Protocol: Article 12(g) unequivocally states that the CEP shall provide advice on the operation and further elaboration of the Antarctic protected area system. All proposed management plans for ASPAs and ASMAs shall be forwarded to the CEP for advice (Article 6.1 of Annex V). The CEP may propose an area for designation as an ASMA or ASPA by submitting a proposed management plan to the ATCM (Article 5.1 of Annex V)[169]. The CEP shall be informed each year of the number and nature of permits issued under Annex V (Article 10.2) and of measures taken to implement Annex V, including any site inspection, and any steps taken to address instances of activities in contravention of the provisions of the approved management plans for ASMAs and ASPAs (Article 10.4, Annex

[169] It should be noted that the CEP can propose an area for designation as an ASMA or ASPA as can any Party to the Treaty, the Scientific Committee of CCAMLR and SCAR (which used to be the only advisory body allowed to fulfill this task).

V of the Protocol).

However, the Protocol does not describe how the CEP will operate, nor how the information required to formulate advice will be gathered and analysed. It is here that the use of GIS has considerable potential as a tool to reinforce the advisory capacity of the CEP.

(i) Definitions of GIS

Fisher and Nijkamp define GIS as "a computer-based information system which attempts to capture, store, manipulate, analyse and display spatially referenced and associated tabular attribute data, for solving complex research, planning and management problems"[170]. This broad definition can be completed by describing the different elements GIS usually embodies. According to Fisher and Nijkamp, these are:

- a database of spatially referenced data consisting of location and associated tabular attribute data, and
- appropriate software components encompassing procedures for the interrelated transactions from input via storage and retrieval, and the adhering manipulation and spatial analysis facilities to output, and
- associated hardware components including high resolution graphic displays, large-capacity electronic storage devices which are organized and interfaced in an efficient and effective manner to allow rapid data storage, retrieval and management capabilities and facilitate analysis[171].

Bracken and Webster provide a functional definition of an information system which is particularly relevant to the need of strenghtening the advisory capacity of the CEP, since their definition focusses upon the value added to the information output by the system. The term 'information system' refers to a system, usually computerized, which is designed to input data, store it, manage it, process it and output it in the form of meaningful information. As Bracken and Webster remark, the end product, information, will normally be a composite entity, constructed from more than one data item. "The system can be thought of in this way as a value-adding processor, adding 'meaning value' to data. The more relevant and finely tuned the information output by the

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[170] Fisher, M.M., Nijkamp, P., 1993, *Geographic Information System, Spatial Modelling and Policy Evaluation*, Berlin: Springer-Verlag, p.3.

[171] Fisher, M.M., Nijkamp, P., op.cit, supra n°61, p.344.

system, and the more timely its delivery, the more it will contribute to the reduction of uncertainty"[172].

According to this functional definition of information systems, GIS can be thought as a specialized form of database system, distinguished by its ability to handle geographic data, that is: spatially referenced data which can be displayed graphically as map images.

(ii) Applications of GIS in international law and international organisations

In international law, GIS has recently been used for gathering and analysing information for conflict resolution. For instance, the Canadian litigation team used GIS in the maritime boundary dispute over a 200 mile zone off St Pierre and Miquelon claimed by France at the International Court of Arbitration of New York in 1991: the Canadian team created an integrated database that could store the data to be used as evidence in support of its arguments. GIS was used to describe the distribution, monetary value, productivity and overall importance of the fisheries resources. Potential boundary solutions based on outcomes of other maritime boundary cases were overlaid on the distributions to identify the resources at risk and assess their possible implications. The Canadian team used GIS in the maritime boundary dispute to complete a detailed fisheries impact assessment and confirm that the overwhelming proportion of fisheries resources will remain under Canadian jurisdiction. Canada prevailed in this arbitral decision thanks to its capacity to display and synthesise geographic information[173].

More generally GIS is designed and implemented on the assumption that more information will have a positive effect on the decision making process, and this is perhaps its more important application. With respect to the advisory role of the CEP, the use of GIS would increase the objectivity of the advice formulated and presented to ATCM, particularly in assessing the adequacy and effectiveness of the measures contained in the management plans for ASPAs and ASMAs. As Aschenbach notes:

An important concept to understand when considering the benefits of a GIS is the difference

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[172] Bracken, I., Webster, C., 1990, *Information Technology in Geography and Planning*, London: Routledge, p.26.

[173] Welgan, P., 1992, GIS and the Law: GIS Plays Key Role in Maritime Conflict, *GIS World*, volume 5, n.8, p.62.

between *ad hoc* and *a priori* data gathering. *Ad hoc* gathering is the traditional method of gathering data at the time a dispute arises. *A priori* data gathering occurs before a dispute arises in anticipation of the event. In an *a priori* system such as GIS, data exists in a central location. The information is gathered in anticipation of the need by many, and the costs of gathering the information can be shared among many end-users. The conventional *ad hoc* system requires information to be gathered at every conflict, causing inefficiency, excess cost, and redundant information gathering[174].

This observation also bears upon the reactive approach of SCAR in providing advice to ATCM on an *ad hoc* basis. By contrast, the CEP could take a proactive approach to fulfilling its advisory functions if management tools such as GIS were available for displaying, gathering and analysing of data on ASPAs and ASMAs.

With respect to international organizations, the Global Resource Information Database (GRID) established by the United Nations Environmental Programme (UNEP) illustrates current applications of GIS in natural resources management. GRID-Arendal (in Norway) opened in 1989 as a polar and nordic link in the network. The aim is to develop an Arctic Environmental Protection Agency focusing on Arctic habitat protection. GRID-Arendal supports this by gathering and presenting information on conservation and protected areas as maps, using GIS techniques. As Husby describes it:

GRID does not engage in primary data collection, but takes advantage of what other institutions have already produced. Its goal is to contribute to the integration of knowledge and information from a range of existing monitoring and research activities, aiming at global, regional and national overviews of environmental conditions. GRID acts as a catalyst, bringing key persons and institutions together, and provides the infrastructure necessary for efficient information handling.[175]

The example of GRID-Arendal could be transposed to the CEP, which would not be engaged in primary data collection, but would rely on the information required in the management plans for ASPAs and ASMAs (described in Article 5 of Annex V). This information could be gathered in a GIS database in order to assess the effectiveness of management plans and to compare the management procedures of different ATPs.

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174 Aschenbach, R.J., 1991, GIS as a Decision Making Tool, *Ohio State Law Journal*, volume 52, part I, p.357.

175 Husby, E., 1993, GRID-Arendal Bridges the Gap, *GIS Europe*, volume 2, n°6, pp.30-33.

Precedents for a GIS database for Antarctica already exist within the International Centre for Antarctic Information and Research (ICAIR) for the Ross Sea region. The GIS database for the Ross Sea region is used for overlaying scientific and management information for the review of management plans for SPAs in the Ross Sea region, since previous plans must now be revised to meet the requirements of Annex V. As Smith notes:

Managers of Antarctic programmes need scientific information on the status and trends within ecosystems and on the risks and possible impacts that activities could cause. A joint NZ-US initiative to develop a management plan for Ross Island will become an integral part of the GIS database for the region. The area has significant wildlife, botanical, historic and tourist resources, and a coordinated approach to management will ensure that these can be conserved and the value and effectiveness of scientific programmes can be enhanced. GIS will play a pivotal role by integrating and synthesizing the necessary information[176].

In feasibility terms, ICAIR's application of GIS demonstrates that a GIS database for all Antarctic protected areas could be developed and that information could be centralised within the relevant institution. Indeed, the provisions of the Protocol (described at the beginning of this section) require the CEP to become the relevant body for centralizing environmental data with respect to ASMAs and ASPAs.

(iii) A suggested information management regime for the CEP

The information management scheme which is proposed here would enable the CEP to operate at a high level of effectiveness. The development of a GIS database for protected areas would help to devise standard formats for information management and thus facilitate comparison, evaluation and analysis.

It would involve different levels of information. Firstly, an overview of the information which can be derived from the management plans, describing each protected site, and maps delineating boundaries, would be constructed. Maps should be large scale to illustrate all the features described in the inventory of the protected site. To achieve this, it is suggested that a topographic base map with thematic overlays be used.
The database would provide a second level of information by describing the

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[176] Smith, S.M., 1993, Understanding the Antarctic, *GIS Europe,* volume 2, n°6, p.38.

management activities to be undertaken, including zoning of areas for which specific regulations apply. A third level of information would correlate information management with the information derived from monitoring programmes undertaken in protected areas. The aim of overlaying the two types of information would be to ensure that the management plan is working and to measure any changes occurring at the site. It would also incorporate EIAs prepared for activities which are likely to have an impact on protected areas. Finally, the GIS database could maintain information on issuing permits and on the requirements for reporting of site visits.

To become operational, the GIS database for protected areas to be run by the CEP would need to overcome a number of difficulties. One problem is to ensure data comparability and compatibility when gathering information from a variety of different sources. Guidelines for the standardisation of data need to be developed. The database would also need to be regularly updated. This might be done by a staff member of the CEP, acting as an auditor for protected areas. A database manager in charge of operating and maintaining the database would also need to be employed. The main resource needed to create a GIS database for Antarctic protected areas is a commitment from Antarctic Treaty Parties to long term funding and to meet operational costs of salaries for a manager and staff. As Shears notes:

> A centralised database is required for all Antarctic protected areas. However, the collection of scientific information for protected areas will involve resource costs both in the field and with the development and maintenance of a database. In the field, funding would normally lie with national operators. Responsibility for the database would rest with Antarctic Treaty Parties, although this responsibility could devolve on the WCMC, SCAR or IUCN by agreement, if and when the Antarctic Treaty develops an acceptable strategy and provides adequate resources[177].

4. Conclusion

With the adoption of the Madrid Protocol, the Antarctic protected area system evolves toward a regional planning approach to conservation, characterised by management measures and a zonation system for protected areas. In this respect, it follows trends in international designations initiated by the World Heritage Convention and the Biosphere Reserve mechanisms. These precedents

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[177] Shears, J.R., Summary and conclusions, In: Lewis-Smith, R.I., Walton, D.H.W., and Dingwall, P.R., op.cit, supra n° 125, p.135.

do not automatically apply to the Antarctic protected area system and they have been analysed to illustrate possible future developments within the context of the ATS.

Despite the new provisions described in Annex V, the Antarctic protected area system lacks means to ensure that a "systematic environmental-geographic framework" approach will be implemented for the identification and designation of future protected areas. Annex V contains no provisions to ensure a uniform implementation of management procedures for protected areas among the various Antarctic national operators.

Considering the advisory role of the CEP in the implementation of the five Annexes to the Protocol, and specifically Annex V, it is essential for this body to be able to centralise all relevant information concerning the management of protected areas. Moreover, the CEP will be required to provide an analysis of this information based on an assessment of the measures contained in the management plans for ASPAs and ASMAs, when providing its advice to Antarctic Treaty Consultative Meetings.

The examples of databases run by PADU, GRID-Arendal and ICAIR demonstrate the different functions for which they can be used and how they could help fulfil the advisory role of the CEP. The capacities of GIS have thus been outlined, in terms of gathering, analysing and displaying data for reports. It is therefore proposed that a GIS environmental database be created, to gather information on ASPAs and ASMAs, and be run by the CEP for the implementation of Annex V.

Chapter IV:

Geographic Information Systems and Environmental Decision Making within the Antarctic Treaty System: Future Applications within the Framework of the Committee for Environmental Protection

1. Introduction

In the previous chapter, the need for a GIS environmental database to be run by the CEP for the implementation of Annex V was argued, with particular reference to GIS applications at a regional level in Antarctica and on a global scale within international organisations. This chapter aims at demonstrating the link between the provisions of the Protocol and GIS capabilities to provide a decision making tool within the framework of the CEP, considering its future role as an advisory body to the Antarctic Treaty System. The CEP's need to become capable of delivering informed advice will be discussed and translated into GIS capabilities such as spatial analysis. The range of GIS applications that could be utilised by the CEP in fulfilling its functions will then be described.

2. Holism as a methodological justification for using GIS

In contrast with populated areas of the world where economic criteria are predominant in the decision making process, in the Antarctic context such criteria are mainly confined to a cost-benefit analysis of the achievements of science and support logistics. This characteristic is now reflected in the designation of Antarctica as a natural reserve devoted to peace and science. In this context and to a greater extent than elsewhere, scientists, through SCAR, have traditionally played a crucial role in providing knowledge and advice upon the state of the Antarctic environment to decision makers such as Consultative Parties to the Antarctic Treaty. However with the new provisions of the Madrid Protocol focusing on environmental management and regional planning, it can be argued that a more holistic approach to environmental decision making is required and, to this end, new tools capable of synthesising and analysing large amount of spatial information. As Zonneveld notes, important benefits are to be drawn from adopting a holistic approach to environmental decision making:

> The essential aspect of holism as a scientific assumption is that it provides the basis for studying certain wholes or systems (for example, an organism) without knowing all the details of their

internal functions. Thus, holism permits the simplification of scientific activity by reducing analytic observations to better understand very complex structures and processes. At the same time it warns against attempting to study wholes by analyzing them in separate pieces without connecting them with each other. Criticism of holists would be justified if they denied the usefulness of gradually making the black boxes more transparent by analytical study. The importance of holism is that in many cases the objects of study -like life and landscapes- are so complex that real understanding gained by working from the basic elements upwards would be extremely difficult, time consuming, and hence expensive -if it were even possible[178].

The environmental information derived from such an approach can be enhanced by using geo-referenced data to support spatial analysis in order to generate maps as information outputs. According to Rogerson and Fotheringham, spatial analysis is concerned with the investigation of patterns in spatial data: "in particular, in seeking possible relationships between such patterns and other attributes or features within the study region, and with the modelling of such relationships for the purpose of understanding or prediction"[179]. GIS is capable of implementing such techniques with an emphasis placed on mapping outputs to convey complex information that can be updated over time as new data are obtained. The predictions derived from spatial analysis are essential to the production of informed advice and consequently to the formulation of sound decision making. According to Zonneveld, holism gave an impetus to the development of general systems theory and of modern computers which provided an important tool - modelling - to bridge the gap between pure analyst and holist. Zonneveld argues that despite the fact that the most complicated model is still an oversimplified imitation of reality, at least it allows for the visualisation of major cybernetic loops and of mechanisms that form the ecological system. Moreover, recent developments in the hard- and software for GIS have extended the integration of different land attributes which enhances the analysis of surveyed landscape data. Ultimately such developments offer new opportunities to extend the models with cartographic input and output.[180].

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[178] Zonneveld, I.S., 1990, Scope and Concepts of Landscape Ecology as an Emerging Science, In: (Zonneveld, I.S; Forman, R.T.T., eds.), *Changing Landscapes: An Ecological Perspective,* N.Y: Springer-Verlag, pp.3-20.

[179] Rogerson, P.A., Fotheringham, S., 1994, GIS and Spatial Analysis: Introduction and Overview; In: (Rogerson, P.A., Fotheringham, S., eds.), *Spatial Analysis and GIS,* London: Taylor & Francis, p.16.

[180] Zonneveld, I.S., op.cit, supra n° 178.

Considering the advisory functions of the CEP to Antarctic Treaty Consultative Meetings (ATCMs), it appears to be the most appropriate body to synthesise and convey information from researchers to decision makers. However, to fulfil this role effectively it is essential that the CEP be provided with tools such as GIS if a proactive and holistic approach to environmental management and regional planning is to be implemented. Above all, it is time the issue of information transfer to decision makers is considered in the context of a reinforced environmental protection regime in Antarctica. The informal advisory process that prevailed until the adoption of the Protocol, under SCAR's *ad hoc* working groups, could not depart from a reactive and sectoral approach to environmental management and was unable to prevent environmental degradation resulting from increasing human activities (as we saw in the previous chapter). In this respect, the remarks of Backus concerning biological conservation and integration with land development in Latin America also apply to the Antarctic context. As Backus notes, the concept of transferring information from researchers to decision makers is not new. But the implementation of this concept has not been achieved effectively due to a number of reasons. Firstly, decision makers do not tend to read academic journals and much other information is not easily accessed. Secondly, complex environmental data are often not transformed into information and conveyed clearly so that policy and decision makers are given the technical understanding to establish rational approaches to the management of resources. Thirdly, the approach to resource management planning has been too sectoral, ignoring the physical and ecological connections between artificial sectors such as agriculture, forestry, energy, wildlands, and so forth. Acknowledging the fact that the ability of humans to think and act holistically appears limited, Backus advocates the need for good information processing and presentation as a key component of holistic land use planning[181].

Despite making no specific reference to GIS, the relevance of the difficulties and solutions formulated by Backus to the achievement of a holistic management of natural resources ought to be considered in relation to GIS capabilities. Precedents suggesting a possible application of GIS on a scale comparable to the Antarctic continent will now be examined.

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[181] Backus, E.H., 1989, Closing the Information Gap: the Development of Priorities for Biological Conservation and Integration with Land Development in Latin America, In: *Global Natural Resource Monitoring and Assessment, Preparing the 21st Century, Proceedings of the International Conference and Workshop, 24-30 Sept. 1989,* American Society for Photogrammetry and Remote Sensing, USA (1990), p.1163-1173.

3. Relevant precedents for use of GIS at a continental and multinational scale: the examples of the Australian Resources Information System (ARIS) and of the Coordinated Information on the European Environment Programme (CORINE)

(i) ARIS

The ARIS is a continental scale GIS which has been developed by the Australian Commonwealth Scientific and Industrial Research Organisation (CSIRO) for storing, recalling, searching, manipulating and displaying data on Australia's bio-physical and socio-economic resources[182]. Its use and relevance to Australian policy and decision-support has clear resonances with the Antarctic context. The development of ARIS coincides with the need to establish a comprehensive central repository of quantitative natural and other resource data about Australia which were traditionally held by local governments. By 1982 the capabilities of ARIS to produce thematic maps of re-categorized stored data were proven and modelling capabilities for various applications were then envisaged. As noted by Smith *et al*:

> The function of an information system is to improve a user's ability to make decisions in research, planning and management. An information system involves a chain of steps from the observation and collection of data through their analysis to their use in some decision making process[183].

The applications of ARIS described by Cocks *et al.* range from assessing the suitability of sites for new cities in order to accommodate additional population, to producing an electoral atlas with statistical tables comparing electorates of the Australian parliament, to natural resources applications, the latter being more relevant to the Antarctic. For example, one application aimed to identify combinations of unusual soil and vegetation as candidate areas for inclusion in Australia's national parks system.

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[182] Cocks, K.D., Walker, P.A., Parvey, C.A., 1988, Evolution of a Continental Scale Geographical Information System, *International Journal of Geographical Information Systems,* volume 2, n°3, pp.263-280.

[183] Smith, T.R., Sudhakar Menon, Star, J.L. and Estes, J.E., 1987, Requirements and Principles for the Implementation and Construction of Large Scale Geographic Information Systems, *International Journal of Geographical Information Systems,* volume 1, n°1, p.15.

ARIS also responded to the request from the Australian Man and Biosphere Committee to identify areas of Australian national parks designated as Biosphere Reserves. Once such areas had been mapped, their representativeness was assessed in relation to the biogeographical provinces in which they belong. Provinces without representative reserves were identified along with candidate national parks for representing these zones[184].

(ii) CORINE

A second precedent in the use of GIS at a continental scale that, being multinational, is even more relevant to the Antarctic context, is the creation of the Coordinated Information on the European Environment (CORINE) programme. The CORINE programme was formally established in 1985 by the European Union's Directorate General of the Environment with the aim of "gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community"[185]. As Wyatt, Briggs and Mounsey remark, "while the system is not strictly global in coverage, its parish encompasses much of the continent of Europe - a region of considerable geographic diversity and an area where there is a profusion of data and data sources. In consequence, the challenges which CORINE presents are comparable with the problems of planning for many global systems" [186].

The CORINE programme is centred upon a GIS environmental database set up for the entire European Union as an environmental monitoring and assessment tool. Its aims originally focussed upon three topics of environmental importance:

- biotopes (which involved setting up an inventory of sites of scientific importance for nature conservation);
- acid deposition (which required gathering information on emissions and on

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[184] For further details concerning this research see: Cocks, K.D., Walker, P.A., 1986, *Using ARIS to Evaluate the Biogeographical Spread of Australia's Biosphere Reserves,* CSIRO Division of Water and Land Resources Technical Memorandum 86/22, Canberra, Australia.

[185] *Official Journal of the European Community,* Council Decision on 27 June 1985 on the adoption of the Commission work programme concerning an experimental project for gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community, OJ L 176, 6 July 1985.

[186] Wyatt, B., Briggs, D., Mounsey, H.M., 1988, CORINE: An Information System on the State of the Environment in the European Community, In: (Mounsey, H., Tomlinson, R., eds.), *Building Databases for Global Science,* London: Taylor & Francis, p.379.

risks of damage to flora and fauna);

- protection of the environment in the Mediterranean region (which required gathering information on land cover, quality and use, on water resources and on coastal problems).

The GIS functions used in this context include feature selection and display, statistical analysis and modelling of single and multiple data sets. As Mounsey outlines it:

> The CORINE database was developed as a reaction to existing problems of nature conservation, acid deposition and conflicts of land use in the Mediterranean. But, to be most effective, the creation of environmental databases should be pro-active, backed up with sufficient resources to involve modellers as well as database builders.[187]

Lessons to be learned from CORINE include the need for building an effective information system from the bottom up. Wyatt, Briggs and Mounsey were consultants to the Commission of the European Union with the responsibility for advising on the design and the development of CORINE. They outline the necessity to concentrate, in the initial stages, on the design of the system and the compilation of basic data, rather than on the provision of aggregated information on policy themes[188].

4. Common constraints of multinational environmental databases identified through the experience of the CORINE programme

The constraints experienced through the development of the CORINE programme appear common to multinational environmental databases, a situation which is of particular interest with respect to potential developments of GIS in Antarctica. These include issues of data acquisition, data quality, database volume and update.

The issue of data acquisition is a prerequisite to the operation of any environmental database. In the case of CORINE, the protection and enhancement of ecological resources within the European Union demands a systematic assessment of their present status and future trends. To achieve this

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[187] Mounsey, H.M., 1991, Multisource, Multinational Environmental GIS: Lessons Learnt from CORINE; In: (Maguire, D.J., Rhind, D.W., eds.), *GIS Principles and Applications,* volume 2, Harlow: Longman Scientific & Technical, p.198.

[188] Wyatt, B., Briggs, D., Mounsey, H., op.cit, supra n° 186, p. 394.

with a GIS database, an inventory of the distribution and detailed characteristics, including location, extent, and nature of biological species and habitats represented needs to be established. Such an inventory of resources must also include information upon the vulnerability of species and habitats to change, pressures from human activities and the protection status of species.

The CORINE programme had limited funding for the acquisition of data sets in a digital format. To address this issue, staff involved in building any multi-contributor database need to be capable of reformating data from the varied formats in which they are received. Secondly, because the CORINE programme draws on a variety of sources, the potential for variation in data quality is great. Since most of the data are derived from digitising paper maps, the accuracy of the data is dependent on the original map scale and on the quality of generalisation produced by the cartographer[189]. Additionally, the issue of data quality has an important implication when overlaying several data sets in order to produce a single set combining the attributes of each one. As Mounsey notes, users should be aware of the limitations that map source scale places on the overlaying process. Because of the effect of scale on accuracy and spatial precision, data derived from small scale sources cannot be used with that collected at larger scales[190].

Another issue to consider in the case of large size databases is the accessibility of information to users. In the case of CORINE, the database volume required some form of partitioning. Mounsey describes initial experiments which suggested that partitioning by country would be most appropriate for end users as many queries arose on a country-by-country basis. However, data volumes were still too large to provide acceptable access times. An alternative partitioning of 2 degrees longitude by 1 degree latitude was therefore temporarily constructed until a more extensive use of the database from a variety of different users has been made. Then a final partitioning system was selected[191].

The need for updating multinational environmental databases requires the elaboration of procedures detailing the frequency of update according to the

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[189] For further details on the issue of data accuracy, see: Goodchild, M.F., 1988, The issue of accuracy in global databases; In: (Mounsey, H., Tomlinson, R., eds.) *Building Databases for Global Science*, London: Taylor & Francis, pp.31-48.

[190] Mounsey, H.M., op.cit, supra n° 187, p.195.

[191] Mounsey, H.M., op.cit, supra n° 187, p.195.

type of data. In the case of CORINE programme, the adoption of such procedures has political as well as technical implications. Since national agencies of the member states of the European Union are responsible for the revision of primary data, as opposed to the users or the data holders (the European Union), collaboration at political and technical levels is therefore required for updating the CORINE database.

The issues raised above are not meant to be exhaustive. Furthermore, they need to be considered when establishing the organisational background of GIS environmental databases. Both ARIS and CORINE are presently centralised at one site, but distributed models are now envisaged thanks to improvements in networking and communications technology. However, in both instances some degree of centralisation is required to determine priorities in data acquisition and to gather such data from various sources.

Initiatives such as ARIS and CORINE demonstrate that the relevance of GIS is not merely restricted to local applications but can be applied as an information management tool on a continental and multinational scale. These two examples suggest that, despite no existing precedent in Antarctica, a similar approach could be adopted for this continent.

5. GIS and environmental decision making within the ATS

If a decision corresponds to a choice between alternatives, the process of decision making involves the evaluation of choice alternatives based on certain criteria. A decision rule is a procedure by which criteria are combined to obtain a particular evaluation. GIS provides the ability to predictively model and implement the outcome of a specific decision rule. As Aronoff remarks, models are used to answer questions about what exists now or existed at some point in the past. More importantly, models are also used to predict what will happen or has happened in another location or another point in time. A GIS provides these capabilities by mean of its analysis functions. But, as Aronoff notes, what GIS cannot provide is the human value judgements that define the goals and the values of the organisation that is using the information[192]. This is an important consideration within the context of the ATS.

The ATS has reinforced environmental protection values with the adoption of

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[192] Aronoff, S., 1989, *Geographic Information Systems: A Management Perspective,* Ottawa: WDL Publications, p.189.

the Madrid Protocol, and these values now need to be incorporated into the environmental decision making process. This process will require further elaboration if uniform standards of environmental procedures and assessments on a continental scale are to be established, while national operators and, ultimately, Treaty Parties should remain responsible for environmental management. This shift of competence at the environmental decision making level from national operators to ATCMs is reflected, to some extent, in the creation of the CEP to provide advice on environmental protection and procedures to the ATCMs. However, before the required information can be produced by the CEP and presented to ATCMs, the integration of large amount of data from various sources needs to take place. To this end, tools and methodologies need to be defined.

The first type of data integration required for environmental decision making within the ATS can be described as horizontal: data from disparate sources need to be integrated into a common geographic coordinate system and data acquisition and analysis need to be linked and shared among the CEP and other agencies, such as the International Centre for Antarctic Information Research (ICAIR). Horizontal integration already exists between ICAIR and a number of Antarctic national operators which have agreed to contribute to the development of the Antarctic Master Directory (AMD) and Antarctic Data Directory System (ADDS). ICAIR is holding information from the New Zealand, Italian and American Antarctic Programmes for the AMD[193], whilst France has recently agreed to take part in the Antarctic Master Directory and issued a statement on the question of improved scientific cooperation and information exchange during the XXth ATCM:

> As the agency hosting the Antarctic Master Directory, ICAIR is now responsible for the coordination of all National Antarctic Data Centres as well as for the collection, control, storage and dissemination of these data profiles. To make those tasks easier and more secure, it is essential to develop an information tool allowing scientists from [the] different countries involved to profile the databases they have been able to set up, whatever their scientific project may be[194].

However, as outlined in this quote, the AMD is mainly envisaged as an

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[193] Source : XX ATCM/INF 46, "Antarctic Data", Information Paper submitted to XX ATCM by SCAR and COMNAP, Agenda item 11, April 1996.

[194] XX ATCM/INF16, "The International Antarctic Master Directory and France-New Zealand Cooperation", Information Paper submitted by France, Agenda item 10, April 1996.

instrument to improve scientific cooperation and information exchange with respect to reports of activities that Treaty Parties submit each year for consideration at the ATCMs[195]. Strong institutional barriers remain at national levels with respect to monitoring environmental management and assessment procedures through an advisory body such as the CEP. This situation is likely to prevent further horizontal integration of data from Treaty Parties unless the issue is addressed at a future ATCM.

With respect to the organisational aspects of establishing a GIS environmental database in Antarctica, Harris notes the difficulty of locating and drawing together data from a variety of sources and countries or agencies. According to this author, it may be practically impossible without a professional centre dedicated to such a task[196].

In this context, it appears that the CEP would be the most appropriate body to determine the degree of data centralisation required to fulfil its advisory functions. This does not necessarily imply that the CEP should be the repository of a future GIS environmental database, since the recent developments within ICAIR have outlined the potential of this agency to complete such a task. However, it means that the CEP should be linked to the process of data acquisition and should be provided with network access to such data in accordance with its needs. Such an option would require the institutionalisation of the CEP as a permanent structure provided with the appropriate computer hardware and software along with expert personnel in GIS analysis and modelling techniques. Such techniques are crucial for the operation of the CEP as will be demonstrated in the next section of this chapter.

The CEP will become active when the Madrid Protocol enters into force. In the meantime, the Transitional Environmental Working Group (TEWG) fulfils the CEP's advisory role. At the XXth ATCM, the TEWG acknowledged the need for a mechanism to consider post-analyses of environmental assessments of Treaty Parties as a means of monitoring the implementation of these measures. The TEWG reported on the application and implementation of Environmental Impact Assessment (EIA) procedures in the following terms:

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[195] See Article 17 of the Madrid Protocol, Antarctic Treaty System, 1991 a; Protocol on Environmental Protection to the Antarctic Treaty, In: *Final Report of the XIth Antarctic Treaty Special Consultative Meeting,* Madrid, Spain.

[196] Harris, C.M., 1993, *Environmental Management in Antarctica using Geographical Information Systems,* Unpublished PhD Thesis, University of Cambridge, U K, p.199.

The TEWG agreed that it was important to find mechanisms that provide feedback from the work accomplished by different countries on environmental impact assessments. The group recommended to the ATCM that post-analyses of environmental assessments should become standard practice, and that Parties should report on the results of these analyses to the ATCM as to how they have implemented those measures. It was recognised that a mechanism to consider these reports needed to be developed[197].

Providing there is horizontal integration of environmental data relevant to the activities of all Treaty Parties into a GIS database accessible by the CEP, the spatial analysis and modelling capabilities of GIS would appropriately satisfy the recommendation formulated above by the TEWG.

The second type of data integration required for environmental decision making within the ATS can be described as vertical: it needs to aggregate data across scales from detailed local studies up to regional and continental assessments. Vertical integration is a component of GIS capabilities. Indeed, in a computer-based GIS, the storage and presentation of geographic data are separate. The data may be stored at a high level of detail and then plotted at a more general level and at a different scale. Consequently, the same data may be viewed as many different types of maps, each map being customized for a specific use. In addition to maps, the data may also be presented in the form of tables[198].

A third type of data integration, unique to GIS, is also relevant in this context: it focuses upon the integration of geographical and attribute data. Geographical data (or spatial data) are referenced to locations on the earth's surface using a standard system of coordinates. Attribute data is also termed non-spatial attribute data in that they do not in themselves represent locational information but describe the geographic coordinates of a particular feature to which they refer. They consist of values or attributes associated with specific points, lines, cells, irregular polygons or a regular grid. For example, the ARC/INFO system from the Environmental Systems Research Institute (ESRI)[199] stores the non-spatial attribute data in the INFO database management system while the ARC

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[197] XX ATCM/WP 32(Rev.1), "Final report of the Transitional Environmental Working Group", Working Paper submitted by the Secretariat, May 1996.

[198] Aronoff, S., op.cit, supra n° 192.

[199] Environmental Systems Research Institute Inc., 381 New York Street, Redlands, CA., 90373, USA.

system provides for the storage and manipulation of the spatial data.

GIS can be considered an extremely useful tool in support of the environmental decision making process within the ATS for several reasons: firstly, as an inventory tool used to record and classify observations, thanks to its storage and retrieval functions; secondly, for its ability to analyse spatial and attribute data together using GIS query functions; thirdly, as a modelling tool in order to predict the behavior of the real world for the phenomena of interest. In the latter and more sophisticated case, the success of GIS relies mainly on the criteria used to evaluate the model and whether these reflect the values of the organisation. In Antarctica, broad definitions of criteria for environmental protection and assessment are already contained in the provisions of the Madrid Protocol[200]. However such broad definitions would gain in precision if a tool such as GIS was used, as will be demonstrated in the last section of this chapter, wherein the aims of a case study in the Windmill Islands, Wilkes Land, Antarctica are described. Moreover, GIS would introduce standard methods and criteria applicable to all Treaty Parties, thus introducing a greater objectivity in environmental decision making. Considering that ATCPs are to base their environmental decisions upon the advice delivered by the CEP, the objectivity of the latter is largely dependent on the analytical tools with which the CEP will be provided.

With the implementation of the Madrid Protocol, the ATS faces new challenges with respect to environmental management in Antarctica. As a French diplomat, Georges Duquin, notes:

> We also face a challenge when the Madrid Protocol enters into force, perhaps in two years. The Committee for Environmental Protection is not going to be the working group that we used to know, but is going to be a committee of scientists, diplomats, managers. This will be a complex affair and will be another new area for cooperation[201].

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[200] Article 3 of the Protocol details a list of environmental principles applicable to the planning and conduct of all activities in the Treaty Area. Article 8 sets out three types of environmental impacts (less than minor or transitory, minor or transitory, more than minor and transitory); and lists the type of activities for which environmental impact assessment are to be applied.

Annex I refers to environmental impact assessment procedures, Annex II refers to the conservation of Antarctic fauna and flora, Annex III refers to waste disposal and waste management, Annex IV refers to the prevention of marine pollution, Annex V refers to area protection and management.

[201] Duquin, G., 1996, New areas for cooperation: logistics, communication, research, tourism; In:

Because the Protocol does not detail how the CEP will operate, this question remains to be answered by the Treaty Parties providing that a consensus can be reached at a future ATCM. This issue will determine whether the ATS as an international government organisation will adjust its initial objectives of structuring communication and cooperation for logistics and scientific purposes to the critical issue of international environment management. The creation of a new advisory body such as the CEP is meant to reflect such an adaptation to changing priorities in Antarctica. As Caldwell notes, the emergence of international environmental policy has been based upon *ad hoc* structures that do not provide a complete or comprehensive system for the implementation of policy. The explanation for this situation is that, despite the existence of the United Nations organizations, NGOs and scientific unions, the operational responsibilities remain almost wholly at the national level. A more comprehensive operational system is necessary and could be achieved through appropriate institutional arrangements. The institutions that are required would compensate for the limitations of the nation state system and strengthen the capabilities of the international legal system with respect to the implementation of agreed policies[202].

Considering the range and the complexity of the CEP's tasks, recommendations concerning its mode of operation need to be urgently formulated. The relevance of GIS for information management and analysis will be outlined in such a context.

6. GIS analysis and applications relevant to the tasks of the CEP

According to Article 12(1) of the Protocol, the CEP will exercise advisory functions upon the specific aspects of its implementation. The provisions of Article 12(1) can be classified into three groups, each corresponding to different aspects of environmental protection.

The first of these is the group of *environmental monitoring* provisions (Article 12(1) a, f, h, k) which detail the advisory role of the CEP on:

(Jackson, A.W., ed.), *On the Antarctic Horizon: Proceedings of the International Symposium of the Future of the Antarctic Treaty System, Ushuaia, Argentina, 20 to 24 March 1995,* Hobart: Australian Antarctic Foundation, p.27.

202 Caldwell, L.K., 1990, *Between Two Worlds: Science, the Environmental Movement, and Policy Choice,* Cambridge: Cambridge University Press, p.158.

a) the effectiveness of measures taken pursuant to this Protocol;

f) procedures for situations requiring urgent action, including response action in environmental emergencies;

h) inspection procedures, including formats for inspection reports and checklists for the conduct of inspections;

k) the need for scientific research, including environmental monitoring, related to the implementation of this Protocol;

The second is the group of provisions contained within *environmental management* (Article 12(1)b, c, g, i) which detail the advisory role of the CEP on:

b) the need to update, strengthen or otherwise improve such measures;

c) the need for additional measures, including the need for additional Annexes, where appropriate;

g) the operation and further elaboration of the Antarctic Protected Area system;

i) the collection, archiving, exchange and evaluation of information related to environmental protection;

Thirdly, there is the group of provisions contained within *environmental impact assessment* (Article 12(1)d,e, j) which detail the advisory role of the CEP on:

d) the application and implementation of the environmental impact assessment procedures set out in Article 8 of Annex I;

e) means of minimising or mitigating environmental impacts of activities in the Antarctic Treaty area;

j) the state of the Antarctic environment [203].

With respect to the use of GIS, this section will elaborate ways of implementing the provisions contained within these three different categories of

[203] Article 12.1 of the Protocol; Antarctic Treaty System, op.cit, supra n°195.

environmental protection. Such a task is required of the CEP through the formulation of recommendations to the ATCMs and, if relevant, to individual Treaty Parties.

(i) Environmental Monitoring

Article 3.2 (d) and 3.2 (e) of the Madrid Protocol call for "regular and effective monitoring to allow assessments of the impacts of ongoing activities, including the verification of predicted impacts", and "to facilitate early detection of the possible unforeseen effects of activities". In practice, environmental monitoring relies upon baselines. These are defined by Walton and Shears[204] as "the collection of essential measurements which establish descriptions of selected environmental indicators. The baseline data acts, therefore, as a datum from which any subsequent observed changes can be measured and compared". Because environmental monitoring usually needs to be undertaken for long periods of time, it is important to establish an effective system for the management and storage of baseline data. In this respect the capabilities of GIS are emphasized by Walton and Shears, as follows:

> Recently, attention has been drawn to the potential of using Geographical Information Systems (GIS) to store, integrate, visualize and analyze different environmental datasets for different variables within a specifed area. Sequential datasets can also be handled and interrogated. GIS systems, therefore, are powerful tool which could help in the management of the environmental impacts of human activities in Antarctica[205].

The need for scientific research, including environmental monitoring, related to the implementation of this Protocol (Article 12.1(k)) can be identified through GIS overlaying techniques which allow detection of changes and analysis of the difference in the same parameters over different time frames. For example, GIS can be used to assess the potential threat posed by human activities to aspects of the Antarctic environment, enabling disturbance to be quantified and results to be used as inputs for a management plan. The Rondane National Park GIS case study, in Norway, provides a relevant example of the capabilities of GIS to investigate the potential threat of increasing tourist pressure on the population

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[204] Walton, D.W.H., Shears, J., 1994, The Need for Environmental Monitoring in Antarctica: Baselines, Environmental Impact Assessments, Accidents and Footprints, *International Journal of Environmental and Analytical Chemistry*, volume 55: 77-90, p. 85.

[205] Walton, D.W.H., Shears, J., op.cit, supra n° 204, p.84.

of reindeer[206].

However, recommendations on the need for scientific research, including environmental monitoring, and on the effectiveness of measures taken pursuant to this Protocol (Article 12.1(a)), can only be formulated by the CEP if baseline data exist and can be accessed. In accordance with Article 12.2 of the Protocol, links need to be developed between the CEP and SCAR, which remains the main body responsible for the coordination of Antarctic research. But, as Champ et al. remark, "our present knowledge about polar environments is too limited in many areas to monitor and interpret from the data the impact of human activities"[207]. This issue has been addressed at the XVIIth ATCM, when Antarctic Treaty Parties adopted Recommendation XVII-1, urging that governments, through their SCAR National Committees request SCAR to consider and provide advice on:

(i) The types of long-term programmes, if any, necessary to verify that human activities (such as tourism, scientific research or other activities) do not have significant adverse effects on birds, seals, plants, and
(ii) emission standards that should be established to ensure that the combustion of fossil fuels and incineration waste do not contaminate the Antarctic atmosphere, terrestrial, ice, aquatic or marine environments in a way that would compromise their scientific values[208].

In the context of this recommendation, the role of the CEP is to obtain through SCAR baseline information on the environment in order to evaluate the effectiveness of conservation measures, regulatory mechanisms and procedures for operating and managing human activities.

On one hand, the CEP should be able to formulate requests for surveys which would provide baseline data on biotic features to be incorporated into the GIS database. Using Global Positioning System (GPS) devices, data can be collected in the field in the form of geographic coordinates, along with their attributes,

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206 Fry, G.L. ; Norris, S., Gjelland, M., Dahle, E., 1992, The Use of Geographic Information Systems in National Park Management: the Rondane National Park Case Study; In: (Willison, J.H.M.,Bondrup-Nielsen, S., Drysdale, C., Herman, T.B., Munro, N.W.P., Pollock, T.L., eds.), *Science and Management of Protected Areas,* Amsterdam: Eslevier, pp.481-484.

207 Champ, M. A., Flemer, D. A., Landers, D. H., Ribic, C., DeLaca, T., 1992, The Roles of Monitoring and Research in Polar Environments, *Marine Pollution Bulletin,* volume25: 9-12, p.223.

208 Recommendation XVII-1 Environmental monitoring and data management, In: *Handbook of the Antarctic Treaty System,* Eighth Edition, April 1994, U.S Department of State, p. 2266.

and later entered into a GIS database[209]. Such methods would enable more efficient and cost-effective sampling design for the inventory of biotic features to take place, since the need for data collection would be identified in accordance with the information missing in the GIS database. This would also avoid sample bias with respect to the representativeness of the data collected. For example, if data was to be collected on vegetation, the sampling design would have to reflect the topographic conditions of the terrain and ensure that data would be collected in all relevant locations.

On the other hand, the CEP should be able to access national and international long-term ecological research via the Antarctic Data Directory (for example), and particularly programs concerned with the investigation of ecological processes related to habitat or species conservation. This is feasible since Recommendation XVII-1 already recommends that "governments provide a list of the Antarctic data sets being compiled and archived by their nationals and make this list available to other Parties, SCAR and CONMAP, as soon as possible to form the basis for the development of an Antarctic Data Directory"[210]. Moreover, the CEP should ultimately be responsible for monitoring the impacts of an event or a development, which will be detailed in the next section on environmental impact assessment.

Procedures for situations requiring urgent action (Article 12.1(f)) can be recommended on the basis of simulations of environmental emergencies, such as oil spills for example, which can be modelled through GIS functions. Concerning inspection procedures, including formats for inspection reports and checklists for the conduct of inspections (Article 12.1(h)), these could be extremely useful to provide the information required in order to fulfil the environmental monitoring provisions detailed above (Article 12.1(k) and (a)). Through GIS query functions, specific locations where increased human activities interfere with the natural environmental can be identified and recommendations for inspection can be formulated. Similarly, missing information can be identified and incorporated within updated checklists for the conduct of inspections at a particular location in Antarctica.

As outlined in the previous chapter of this thesis, monitoring the impacts of ongoing activities is a new field falling outside the scientific career and funding

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[209] See the methodology used for the collection of data required for the Windmill Islands case study described in the following chapter of this thesis.

[210] Recommendation XVII-1, op.cit, supra n°208, p.2266.

system. With the Madrid Protocol, environmental monitoring falls within the competence of the CEP, which is responsible for the formulation of recommendations on this issue to the ATCMs. Therefore, for such monitoring to become effective, the resources and personnel involved in the identification of appropriate information, GIS modelling functions and inspection procedures need to be considered. Such tasks can only be achieved within a permanent organisational structure and with adequate funds.

(ii) Environmental management through a GIS database management

The issue of collection, archiving and exchange of information related to environmental protection (Article 12.1(i)) can be addressed with the information storage and retrieval capabilities of GIS. Information evaluation can be achieved through constrained query functions, allowing questions such as "which protected area contains the largest colony of snow petrels in Antarctica" to be formulated. In order to formulate recommendations on the need for or to update environmental protection measures (Article 12.1(b) and (c)), local, regional and continental overviews of the state of the environment and of human impacts are required. Such overviews can be used for determining which particular aspects of environmental management have been neglected and at which particular locations. This issue is common to the other two categories: effectiveness of measures taken pursuant to this Protocol (Article 12.1(a)) and the state of the Antarctic environment (Article 12.1(j)). Such overviews can be rapidly produced by overlaying different data sets (or layers of information) contained in the GIS database using a customised user interface, such as provided by the Arcview program developed by ESRI.

The issue of the operation and further elaboration of the Antarctic protected area system (Article 12.1(g)) is complex. Several analytical and modelling functions are needed in order to meet the requirements of Annex V. The Windmill Islands region case study, based on the identification of areas of biophysical and cultural significance, will demonstrate in the next chapter the usefulness of GIS for meeting the environmental protection criteria set out in Article 3.1 and 3.2 of Annex V. For example, a common deficiency in protected areas, in Antarctica and elsewhere, is the adequacy of their designation for ensuring the conservation of biological diversity (biodiversity). This concept has been defined in Article 2 of the Convention on Biological Diversity as follows:

The variability among living organisms from all sources including, inter alia, terrestrial, marine and aquatic ecosystems and the ecological complexities of which they form part; this includes diversity within species, between species and of ecosystems[211].

In a more comprehensive definition provided by Scott et al, biodiversity refers to the variety and variability among living organisms, which is to be recognized at genetic, species, ecosystem, and often landscape levels of organization. However, the definition of biodiversity provided by the Convention on Biological Diversity appears to be legally more relevant since it encompasses the conservation of all species including the genetic variability which they contain and the ecologial communities they form. The goal of biodiversity conservation is to reverse the processes of biotic impoverishment at each of these levels of organisation[212]. Traditional responses to the increasing loss of biodiversity have focused upon rescuing individual species from extinction. Recent approaches appear to be more proactive in that their aim is to identify areas rich in species and vegetation types which are not represented in existing networks of protected areas. Known as gap analysis because it seeks to identify gaps that may be filled through the establishment of new reserves, this approach uses GIS for the identification and evaluation of unrepresented or under-represented biodiversity areas. Gap analysis is currently implemented in the United States and in Canada and Australia[213]. As Scott *et al.* outline, gap analysis products include maps and tables which summarise the predicted distribution and conservation status of vegetation types and species. Moreover, this method includes a conservation evaluation which identifies areas

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211 United Nations, Convention on Biological Diversity (Rio de Janeiro, June 5, 1992), *International Legal Materials*, 31: 818 (1992).

212 Scott, J. M., et al., 1993, *Gap Analysis: A Geographic Approach to Protection of Biological Diversity*, Wildlife Monograph n°123, The Wildlife Society Inc., pp.1-41.

213 See respectively for the United States: Scott et al., op.cit, supra n° 212.

For a Canadian example, see: Colville, D., Bridgland, J., 1992, GIS Evaluation of Special Preservation Zones in a National Park, In: (Willison, J.H.M.,Bondrup-Nielsen, S., Drysdale, C.,Herman, T.B., Munro, N.W.P.,Pollock, T.L., eds.), *Science and Management of Protected Areas*, Amsterdam: Elsevier, pp.461-465.

For an Australian example, see: Thackway, R. and Cresswell, I., 1995, Towards a Systematic Approach for Identifying Gaps in the Australian System of Protected Areas; In: (Herman, T.B., Bondrup-Nielsen, S., Willison, M., Munro, N.W.P., eds.), *Ecosystem Monitoring and Protected Areas: Proceedings of the 2nd conference on Science and the Management of Protected Areas, Dalhousie University, Halifax, 16-20 May 1994*, Science and Management of Protected Areas Association, Centre for Wildlife and Conservation Biology, Acadia University, Nova Scotia, Canada, pp.473-483.

potentially rich in vegetation types and species. Such areas may be unrepresented or under-represented in biodiversity management areas. Representation of threatened or endangered species within biodiversity management areas is also evaluated. The outcomes of gap analysis therefore provide the means for developing an integrated biodiversity conservation strategy[214].

In Antarctica, a GIS approach to the conservation of biodiversity could be similarly applied through the identification of representative areas in species and vegetation types. Such areas could then be included in the network of protected areas. This task would clearly fall within the competence of the CEP considering its role in the operation and further elaboration of the Antarctic protected areas system.

(iii) Environmental Impact Assessment (EIA)

Article 12.1(d) and (e) of the Protocol[215], referring to the implementation of EIA procedures and to the minimisation of environmental impacts of activities, implicitly acknowledges the need for developing an approach to EIA that is both proactive and which takes a wider view of environmental change, including indirect and cumulative impacts. Article 3.2 (e) and (f) of Annex I states that both indirect and cumulative impacts should be considered in the case of Comprehensive Environmental Evaluation (CEE).

However the Protocol provides no guidelines as to how such impacts should be considered. Attempting to clarify this issue, the International Union for the Conservation of Nature (IUCN) organised a workshop on Antarctic Cumulative Impacts, in 1996. It was then noted that "environmental audits, reviews and monitoring should be used as another tool to assess cumulative impact and associated processes, particularly for on-going activities"[216]. Unfortunately, the

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214 Scott et al., op.cit, supra n° 212, p.9.

215 Article 12.1 states that "the functions of the Committee shall be to provide advice and formulate recommendations to the Parties in connection with the implementation of this Protocol, including the operation of its Annexes(...). In particular, it shall provide advice on (d) the application and implementation of the environmental impact assessment procedures set out in Article 8 Annex I; (e) means of minimising and mitigating environmental impacts of activities in the Antarctic Treaty Area.

216 IUCN, Recommendation 8, Draft report from the workshop on Antarctic Cumulative Impacts held in Washingtion in 1996 (Draft Report).

workshop did not say who would be responsible for conducting such audits, reviews and monitoring. With respect to EIAs, the practice reinforced by Recommendation XIV-2 adopted in 1987[217] is that national Antarctic organisations are to evaluate environmental impacts and the decisions are to be left to national governments. However such an emphasis upon the exercise of sovereignty undermines the credibility and the purpose of EIAs; as Lyons notes:

Self assessment and decision-making by the proponent of the activity is a serious problem for the ATCPs in terms of the external credibility of the process. The involvement of independent experts and bodies will improve this, and without letting the final decision out of the purview of Treaty Parties, more 'teeth' could be given to the Madrid Protocol's Committee for Environmental Protection, especially in the case of activities covered by the CEE processes. The need for an impartial assessment and review will be even more important as the level of non-government activity, such as tourism, increases[218].

Even if the CEP will not be responsible for conducting EIAs and CEEs, this body will de facto need to undertake post-analysis of EIAs and CEEs in order to formulate recommendations upon them. In fact, the TEWG recently recommended that post-analyses of environmental assessments should become a standard practice in order to provide feedback from the work accomplished by different countries on EIAs[219]. The involvement of the CEP in this process is legitimised by the provisions of Article 12.1 (d) and (e) of the Protocol which states that the CEP is to formulate recommendations on the implementation of EIA procedures and means of minimising environmental impacts of activities.

Assuming that links will be established between the CEP and national Antarctic program data systems, the issue of information management and of methodologies for post-analysis of environmental assessments which would include cumulative impacts needs to be adressed. As it was noted at the IUCN workshop on Antarctic cumulative impacts: "Effective procedures for information management are crucial to managing cumulative impacts. It will not be possible to meet cumulative impact obligations without an effective data

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[217] Recommendation XIV-2 Man's impact on the Antarctic environment: environmental impact assessment, In: *Handbook of the Antarctic Treaty System*, op.cit, supra n° 208 , p.2036-2938.

[218] Lyons, D., 1993, Environmental impact assessment in Antarctica under the Protocol on Environmental Protection, *Polar Record,* volume 29, n°169, p.115.

[219] XX ATCM/WP 32 (Rev.1), op.cit, supra n° 197.

management system"[220]. GIS provides a practical means of conducting cumulative impact assessments thanks to its capacity to compile, process and evaluate data collected on both natural and human environments over a long time period and for a large geographic area. As Parker and Cocklin state, GIS has an important role to play within a regionally-based assessment of cumulative environmental change for several reasons. Firstly, GIS can handle large quantities of spatially referenced data. Secondly, GIS is capable of identifying spatial overlaps and proximities and assessing the spatial distribution of impacts. Thirdly, within a scenario analysis, GIS can represent the spatial distribution of anticipated changes and display changes in the state of the environment through time[221].

Moreover, the usefulness of GIS for facilitating cooperation and coordination in areas subject to potential cumulative impacts, such as in multi-national situations, was acknowledged at the IUCN Workshop on Antarctic cumulative impacts. Gaps in current arrangements for exchange and access to operational data relevant to the identification of cumulative impacts, such as records of spills or of types of activities undertaken in certain areas, were also noted. Consequently, the following recommendations were adopted:

- Data or other information should always be provided with GPS references.
- COMNAP and SCAR should examine the feasibility and means of including references to operational databases in the Antarctic Digital Directories.
- The development of a common database containing meta-data should be considered in multiple operator areas[222].

These recommendations coincide with difficulties outlined above with respect to the need for data integration. Until this issue has been practically addressed by Treaty Parties, the implementation of the Protocol is bound to be uneven between Antarctic national programmes and ineffective with respect to the environmental decision making process it describes. Moreover the CEP will have no means of providing informed advice to ATCMs.

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[220] IUCN, op.cit, supra n° 216.

[221] Parker, S., Cocklin, C., 1993, The Use of Geographical Information Systems for Cumulative Environmental Effects Assessment, *Computers, Environments and Urban Systems,* volume 17, pp.393-407.

[222] Respectively Recommendations 13, 14 and 15 of the IUCN workshop on Antarctic cumulative impacts, op.cit, supra n° 216.

7. Conclusion

The Madrid Protocol describes a framework of environmental decision making in which the CEP will operate as an advisory body. However, criteria and procedures for environmental protection upon which the decision making process will be based are likely to remain subject to disparities when implemented by Treaty Parties. To avoid this major flaw, the CEP needs to be provided with means of promoting and supervising environmental monitoring when required by circumstances.

Information on sensitive areas with respect to human impacts and/or natural resources needs to be accessed by the CEP so that this body can deliver informed advice to ATCMs in advance of any environmentally-relevant decision being made. As outlined in this chapter, GIS could provide appropriate answers to such issues. Moreover, it would enhance the operational capacity of the CEP and the objectivity of environmental decision making in helping to generate a standard method for assessing the activities of Treaty Parties along with their impacts upon the environment.

If such capabilities were granted to the CEP, this advisory body would have the potential to become an international government organisation responsible for environmental decision making within the ATS. Such developments would meet the current needs for international environmental management in Antarctica notwithstanding the limitations upon sovereignty that such institutional changes would provoke.

Having outlined in this chapter the benefits the CEP could gain from using GIS as a preliminary tool for environmental decision making, the case study of the Windmill Islands will now be introduced as an example of the CEP's potential role in the future. The aim of this case study is to demonstrate how GIS can be practically applied to the operation and further elaboration of the Antarctic Protected Area System. Such a task clearly falls within the competence of the CEP as detailed in Article 12.1(g) of the Protocol. The methodology that this case study will describe could be implemented by the CEP as a means of providing advice upon the operation and development of the Antarctic Protected Area System, through the recommendation for inclusion of underepresented or threatened areas of biophysical and cultural significance to ATCMs.

Chapter V:

The Case Study of the Windmill Islands, Wilkes Land, Antarctica:

Using GIS to develop a Priority Index for the Identification of Areas of Biophysical and Cultural Significance

Part I. Methodology

1. Research Design

1.1 Relevance of case study research

This case study intends to asks how GIS could be used to assist with the implementation of some of the provisions detailed in Annex V of the Protocol. The context in which this research question will be answered is the future operation of the CEP, once the Protocol enters into force. The potential of GIS as a tool for implementing the tasks assigned to the CEP needs to be practically demonstrated. This demonstration will focus upon the operation and further elaboration of the Antarctic Protected Area System, relying upon the biophysical and cultural criteria described in Article 3.2 of the Annex V. To this end, the overall aim of this case study falls within the definition provided by Yin:

> A case study is an empirical inquiry that investigates a contemporary phenomenon within its real-life context, especially when the boundaries between phenomenon and context are not clearly defined[223].

Concerns have been expressed by Yin about possible shortcomings of case study research. One concern is that case studies generally provide little basis for scientific generalisation. However, the aim of this case study is to show the potential to generalise a GIS methodology for the identification of areas fulfilling the criteria listed in Article 3(2) of Annex V of the Protocol. In other words, it aims to demonstrate that GIS is an appropriate tool for addressing the issue of how the CEP can deliver informed advice on protected areas to Treaty Parties. This aim differs from the limited scope for scientific generalization

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[223] Yin, R.K., 1994, *Case Study Research: Design and Methods,* 2nd Edition, Sage, p.13.

provided by case studies overall, since, in this instance, it provides a theoretical and practical framework of implementation. Another concern formulated by Yin relates to the introduction of biases in case study research that influences the direction of the findings and conclusions. In this respect, a detailed explanation of the GIS methodology along with definitions of the aims and limitations of the case study are essential to identify potential bias. Once bias are identified, they can be included in the discussion of the results. Such requirements will provide the reader with the appropriate information to decide whether it would worthwhile to implement this case study within the organisational context described before.

1.2 Aims of the case study

With the adoption of the Madrid Protocol, the identification of areas of biophysical and cultural significance has become a prerequisite to the designation and management of protected areas. Indeed, Article 3.2 of Annex V refers to a "systematic environmental-geographical framework" that Parties shall seek to identify and to include in the series of Antarctic Specially Protected Areas.

The aims of this case study are: (1) to establish an Antarctic Priority Index in order to identify areas of biophysical and cultural significance which may require protected area designation; (2) to assess the wilderness quality of such areas using the following indicators of human activity: remoteness from settlement, remoteness from access, aesthetic naturalness, biophysical naturalness; (3) to assess the degree of environmental threat for areas affected by human activities. In doing so, the biophysical and cultural values identified will be weighted against the indicators of human activities listed above.

The Priority Index is based on biophysical and cultural values on one hand and constraints to environmental protection on the other hand, that need to be systematically considered for each site. The values are constitutive of a "systematic environmental-geographical framework" as described in Annex V. The constraints represent features of human impacts with a potential to interfere with such values.

Similar methods of site identification and assessment for heritage listing and conservation purposes have already been employed in Australia, with particular reference to the use of GIS 224. However, as outlined in the previous chapter, the identification, assessment and management of sites of biophysical and cultural importance has never been undertaken on a systematic basis in Antarctica, and, to date, protected area designation has been mainly confined to sites of narrowly scientific and biological interest. With the Protocol225, the scope of protected area designation is expanded to an ecosystem approach incorporating biophysical values such as pristine, representative, unique and abundant on one hand; on the other hand cultural values such as the aesthetic and wilderness value of sites is to be considered along with scientific and historical values.

The Windmill Islands region was selected for the case study since a number of data sets were available from the GIS database of the Australian Antarctic Division, such as: topography, station buildings, roads, antennas, vegetation[226]. No faunistic data sets were contained in the GIS database except for the location of penguin colonies, additional information was therefore collected in the field using a global positioning system device in order to record nesting sites of seabirds during the summer 1995-96.

1.3 Interpretation of the biophysical and cultural values listed in Annex V

The following interpretation will be given to the provisions of Article 3 paragraph 2 of Annex V:

(i) pristine value

This value refers to "any areas identified as kept inviolate from human interference so that future comparisons may be possible with localities that have been affected by human activities" (Article 3.2(a) of Annex V). Areas which are remote from settlement and access and whose naturalness has not been altered aesthetically or biophysically will be selected using GIS spatial analysis techniques.

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[224] Lesslie, R.,Abrahams, H.,Maslen, M.; 1993, *National Wilderness Inventory: Handbook of Principles, Procedures and Usage. A report to the Australian Heritage Commission,* Australian Heritage Commission, 18 pages.

[225] Article 3(2) of Annex V on Area Protection and Management.

[226] Coastline, rock/ice interface, contours on rock and spot heights have been produced from ANARE aerial photography dated January 1994.

(ii) representative value

This value refers to "any area identified as a representative example of major terrestrial, including glacial and aquatic, ecosystems" (Article 3.2(b) of Annex V). Areas representative of a number of habitats will be identified and selected as examples for this study. These will correspond to where species currently occur or could potentially occur. Georeferenced techniques will be used to analyse field data with a view towards establishing the representativeness of the sites under consideration. Marine ecosystems will not be considered due to a current lack of relevant data.

(iii) abundance and biodiversity value

This value refers to "any important or unusual assemblages of species" which corresponds to a biodiversity criterion, and includes "major colonies of breeding native birds or mammals" (Article 3.2(c) of Annex V), in accordance with an abundance criterion. Due to the lack of data on density distribution of species contained within the current GIS database, areas can only be selected on the basis of knowledge gathered within the scientific literature and from field observations.

(iv) unique value

This value refers to any area identified as "the type locality or only known habitat of any species" (Article 3.2(d) of Annex V). The interpretation of this value could rely upon the definition provided by Usher and Edwards, since they make a relevant distinction between "type locality" and "only know habitat", as follows: "the type localities are only worth special protection if the species, whose type locality it is, has a very restricted distribution. If the locality is the only known habitat for a species, then the criterion of type locality becomes reduced to that of uniqueness"[227]. For the uniqueness value, too , the current limitations of the GIS database will prevent queries to be formulated. An Antarctic biophysical inventory is required before any assessment of the uniqueness of an area can be undertaken. Such an inventory is currently in preparation for the Australian Antarctic Territory (AAT) as part of the Australian National Antarctic Research Expeditions (ANARE) Strategic Plans[228].

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[227] Usher, M.B., Edwards, M., 1986, The Selection of Conservation Areas in Antarctica: an Example using the Arthropod Fauna of Antarctic Islands. *Environmental Conservation* volume 13, n°2, pp.115-122.

[228] See Australian National Antarctic Research Expeditions (ANARE), 1994, *Strategic Plans 1995-*

(v) scientific value

This value corresponds to any area designated as an ASPA for scientific purposes (ie. the ex-SSSIs) and/or to any site of "on-going or planned scientific research". Designated areas could be identified through a query within the GIS database. Sites of on-going or planned scientific research which are not designated as ex-SSSIs or ASPAs are currently not registered within the GIS database; this is an issue that should be addressed by the Antarctic Division along with the on-going biophysical inventory of the ATT.

(vi) historic value

This value refers to any area included in the list of Historic Sites and Monuments agreed to during Antarctic Treaty Consultative Meetings. Sites could be selected if such information was contained in the GIS database. However, no sites have been listed thus far within the Windmill Islands region.

(vii) aesthetic and wilderness value

This value refers to any area identified as outstanding on the basis of remoteness from access and settlement, aesthetic and biophysical naturalness indicators. The method to identify such qualities utilises a combination of GIS overlay techniques with distance analysis and visibility functions.

It should be noted that the interpretation of the wilderness and aesthetic value overlaps with the pristine value. It is not surprising that areas identified as pristine also have an aesthetic and wilderness value. However, there is a difference between the two types of values in management terms. In order to remain pristine, an area must be excluded from human visitation whereas area of wilderness and aesthetic value can be used for recreational purposes within the limits of the carrying capacity of the site considered and for certain defined types of activities only.

According to Usher and Edwards, uniqueness as a criterion should be used to select sites that stand apart from the representative series of sites. In the case of Antarctica, it is the criterion of representativeness that is the more important since it entails the identification and selection of all ecosystem types. In order to classify ecosystems so that a representative selection can be made, it is also

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2000 , Department of the Environment, Sport and Territories : Commonwealth of Australia, pp.71-77.

important to consider all aspects of the terrestrial biota, including both plants and arthropods[229]. For Usher and Edwards, criteria that are commonly used in other parts of the world such as area of site, diversity, rarity, naturalness, and threat of human interference, are of restricted use in Antarctica considering the limited extent of human presence on a continental scale. However it can argued that the threat of human interference within ice free areas, where human occupation coincides with breeding sites, justifies the need for improved protected area designation using the criteria identified within the Protocol. Indeed, most disturbance and destruction of habitat in Antarctica can be traced to the influence of humans, usually with the development and operation of permanent stations[230]. As Croxall notes, one of the most important requirements is to add to the network of existing reserves so as to achieve a coordinated system ensuring proper protection of all the habitats in which seabirds and seals breed[231].

1.4 Identification of constraints to be considered within the Priority Index

With respect to the constraints that have the potential to diminish the values of sites of potential biophysical and cultural significance, various aspects of human impacts are considered in assessing the aesthetic and wilderness value of such sites. For the purposes of this study, the same indicators are used to determine the aesthetic and wilderness values along with the type and extent of human impacts for the sites under consideration. Definitions of the indicators used in this study have been adapted from the work undertaken in Australia by Lesslie, Abrahams and Maslen with respect to the National Wilderness Inventory[232]. These can be described as follows:

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[229] Usher, M.B., Edwards, M., op.cit, supra n° 229.

[230] The case of Cape Hallett in the Ross Sea, referred to in chapter 3 of this thesis, illustrates such human interference: 8000 to 10000 pairs of Adélie Penguins were evicted during station construction, and the population declined from 62900 pairs in 1959 to 37000 pairs in 1968. While the population increased to its original size after the station was closed in 1972, only few areas modified by man have been recolonised.

Source: Wilson, K.J., Taylor, R.H., Barton, K.J., 1990, The Impact of Man on Adélie Penguins at Cape Hallett, Antarctica. In: (K.R. Kerry, G. Hempel, eds.) *Antarctic Ecosystems: Ecological Change and Conservation*, Berlin: Springer-Verlag, pp.183-190.

[231] Croxall, J.P., 1987, The Status and Conservation of Antarctic Seals and Seabirds: A Review. *Environmental International*, volume 13, pp. 55-70.

[232] Lesslie, R., Abrahams, H., Maslen, M., op.cit, supra n°224.

(i) remoteness from access

This indicator defines the degree to which such access features as an aircraft landing ground, a vehicle track or a wharf modifies the natural aspects of the site under consideration. A quantitative assessment is made by measuring the distance from each location to the nearest access feature. Four grades of access are defined according to the level of access provided and the degree of use received, as follows:

Very high: helicopter landing ground/wharf/established road frequently used.

High: helicopter landing ground/wharf/established road infrequently used.

Medium: vehicle track/landing access for zodiacs frequently used.

Low: vehicle track/landing access for zodiacs/ski and walking track infrequently used.[233]

A total remoteness from access value is derived by assigning a weight to each grade of access to reflect its level of impact on the remoteness of the site considered.

(ii) remoteness from settlement

This indicator defines the degree to which permanent structures compromise the environmental quality of the site under consideration. A quantitative assessment is made by measuring the distance from each location to the nearest occupation feature. Three grades of occupation are defined according to the degree of settlement they represent and the intensity of use, as follows:

Major: station buildings permanently used.

Intermediate: abandoned station buildings, refuges, and field huts frequently used.

Minor: refuges, field huts, field camps occasionally used.

A total remoteness from settlement value is derived by assigning a weight to

[233] If existing, a hard-rock runway would be classified as 'very high' or 'high' level of access depending on the frequency of use. Similarly, a runaway on ice would be classified within the medium and low level of access categories depending on the frequency of use.

each grade of settlement to reflect its level of impact on the remoteness of the site considered.

(iii) biophysical naturalness

This indicator defines the degree to which past and current activities create human-induced environmental change and degradation to the naturalness of each site under consideration. A qualitative assessment is made, relying upon the information available on the type of land use activity (accidental, logistical, scientific, recreational) for each site under consideration. Three grades of biophysical disturbance are defined according to the intensity, duration and nature of the interference. Depending upon the biophysical context (area free of important species assemblages as opposed to faunistic areas for example), recreational, scientific or logisitic activities would have a different impact for the same level of activity (occasional, frequent or long term activity). 'Accidental activities' refer to exceptional circumstances; 'occasional activities' refer to irregular visitation of sites as opposed to 'long term recreational activities' which refer to on-going visitation for recreational purposes.

High: accidental activities causing long-term contamination by introducing pollutants into the environment; use of the site as a waste disposal area; permanent modification/destruction of habitats resulting from logistical, scientific or recreational activities.

Medium: occasional disturbance to the fauna and flora due to logistical/scientific or recreational activities.

Low: long-term recreational use of an area free of important species assemblages.

(iv) aesthetic naturalness

This indicator defines the degree to which human artefacts introduce a visual disturbance in the naturalness of the site under consideration. Levels of aesthetic naturalness will be derived from the GIS analysis of areas of visible disturbance caused by permanent or abandoned structures (such as buildings, roads, dumping-sites, antennas) as opposed to areas where no visible disturbance can be observed.

The method described above is advocated in the implementation of Annex V of the Protocol, as a systematic approach for identifying gaps in the Protected Area System of ice-free areas of Antarctica. In this respect, a similar approach has recently been adopted by the federal and state nature conservation agencies of Australia, in order to revise both the data sets and the methodology leading to the identification of candidate areas which may be investigated for inclusion in the national system of reserves[234].

1.5 Limitations of the case study

This chapter demonstrates that the values detailed in Article 3.2 of Annex V, can be identified and assessed using GIS spatial analysis techniques. Necessarily, this process relies upon the information contained in the current database provided by the Australian Antarctic Division for the Windmill Islands region. It is important at this stage to recognize the limitations of the current GIS data sets in order to explain why GIS techniques could not be applied to the identification of each of the values detailed in Article 3.2 of Annex V. Similarly, information on the distribution and on habitat requirements of most species is not currently available in digital format or in any systematic format that could be used as baseline data. Additional data needs to be collected in the field in order to extend the analysis beyond the range of species present in this study.

Another limitation is to be found in the variability of terrain characteristics below the level of resolution (5 meters) chosen for this study. As a consequence, some degree of confidence has been lost for calculated derived topographic variables such as slope.

No information was available in the GIS database regarding the granular disintegration[235] and the weathering of rocks, both processes which would have helped the identification of habitat requirements for the snow petrels since this species is nesting in crevices formed within rocks.

The implementation of the methodology detailed in this chapter has been restricted to five sites within the Windmill Islands region. The representativeness of these sites is determined by their geographic location and

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[234] Thackway, R., Cresswell, I., 1995, Towards a Systematic Approach for Identifying Gaps in the Australian System of Protected Areas; In: *Ecosystem Monitoring and Protected Areas: Proceedings of the Second International Conference on Science and the Management of Protected Areas, held at Dalhousie university, Nova Scotia, Canada, 16-20 May 1994,* Science and Management of Protected Areas Association, Acadia University, Nova scotia, Canada; pp. 473-483.

[235] Granular disintegration is a process defined by Monkhouse as follows: "the breaking down or crumbling of porous rocks into a granular mass, as a result of freezing following the absorption of water into the pore-spaces". In: Monkhouse, F.J, 1970, *A dictionary of Geography,* London: Edward Arnold, p.162.

their topographic features which are described in the following section. These five examples are intended to show that this methodology could be applied to the whole Windmill Islands region.

1.6 Description of the study area

As shown in Figure 5.2, Bailey Peninsula is located in the northern part of the Windmill Islands and its topographic includes a plateau with a few isolated hills, such as Reeve Hill where the snow petrel colony is (see Figure 5.3). Ardery Island is located in the central part of the Windmill Islands and isolated from the continent by the sea. It is also the most elevated site in the whole Windmill Islands region (Figure 5.4). Peterson island is located in the Southern part of the Windmill Islands, close to the continent (as shown in Figure 5.5 Peterson Island is only separated of Browning peninsula by a small channel), and its topography is made of several hills amongst flat areas. These three sites are therefore representative of the variations in the environmental parameters encountered in the Windmill Islands, such as for example the prevailing winds which are coming from the east in the northern part of the Windmill Islands and from a south and southeast direction in the southern part of the region[236]. Odbert Island and Clark Peninsula are incorporated in this case study in order to validate the GIS methodology described in this chapter. These two sites ensure a complete representativeness of the study sites with a low elevated peninsula located in the northern part of the Windmill Islands (see Figure 5.6 presenting Clark Peninsula) and an elevated island located between Ardery island and the continent (see Figure 5.7 presenting Odbert Island).

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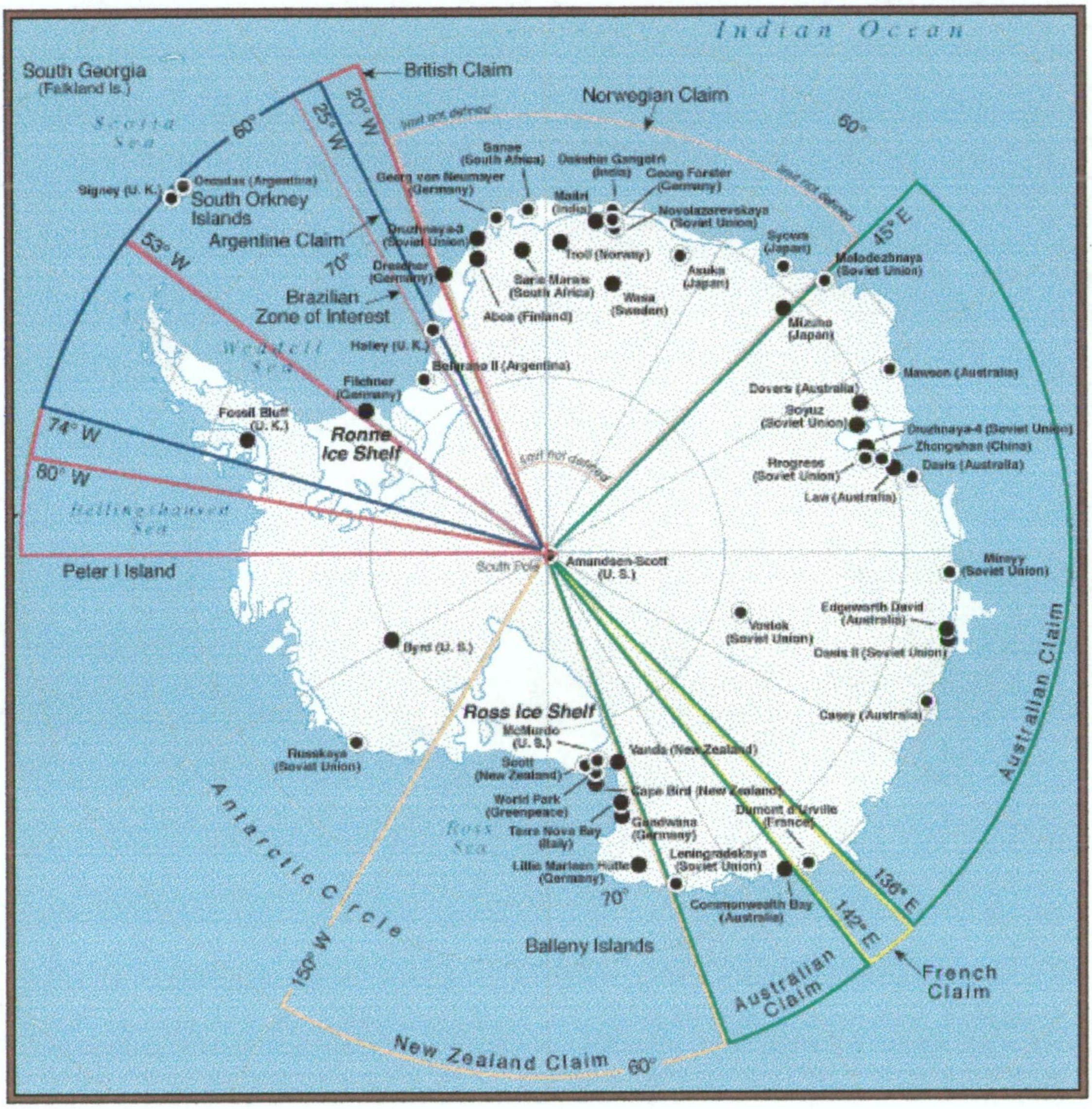
[236] For further details concerning this phenomenon see footnote n° 279 of this chapter.

Figure 5.1: Map of Antarctica



http://www.terraquest.com/va/expedition/maps/continent.gif

Figure 5.2: Locality map of the Windmill Islands

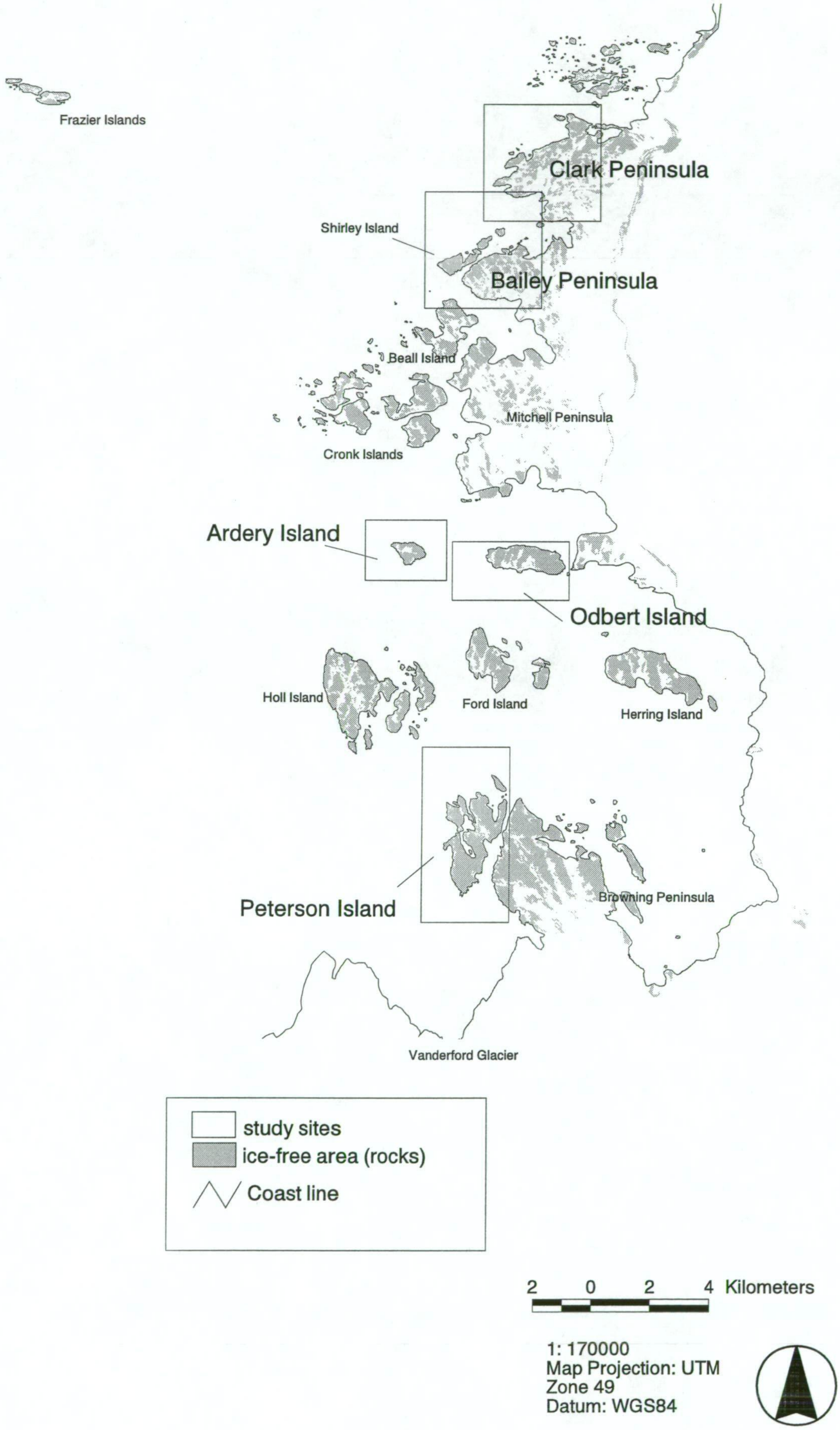


Figure 5.3 : Locality map of Bailey Peninsula

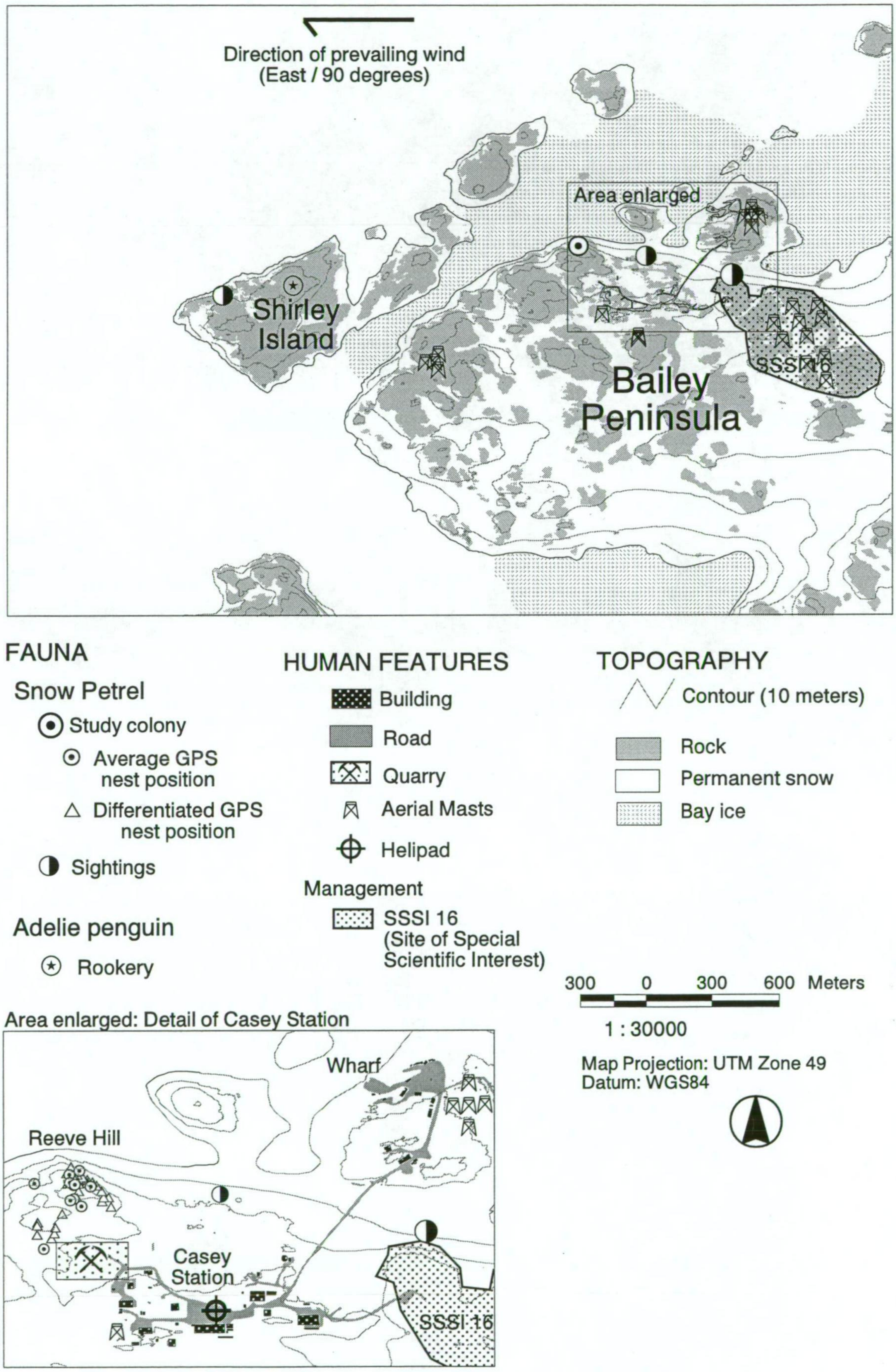


Figure 5.4: Locality map of Ardery Island

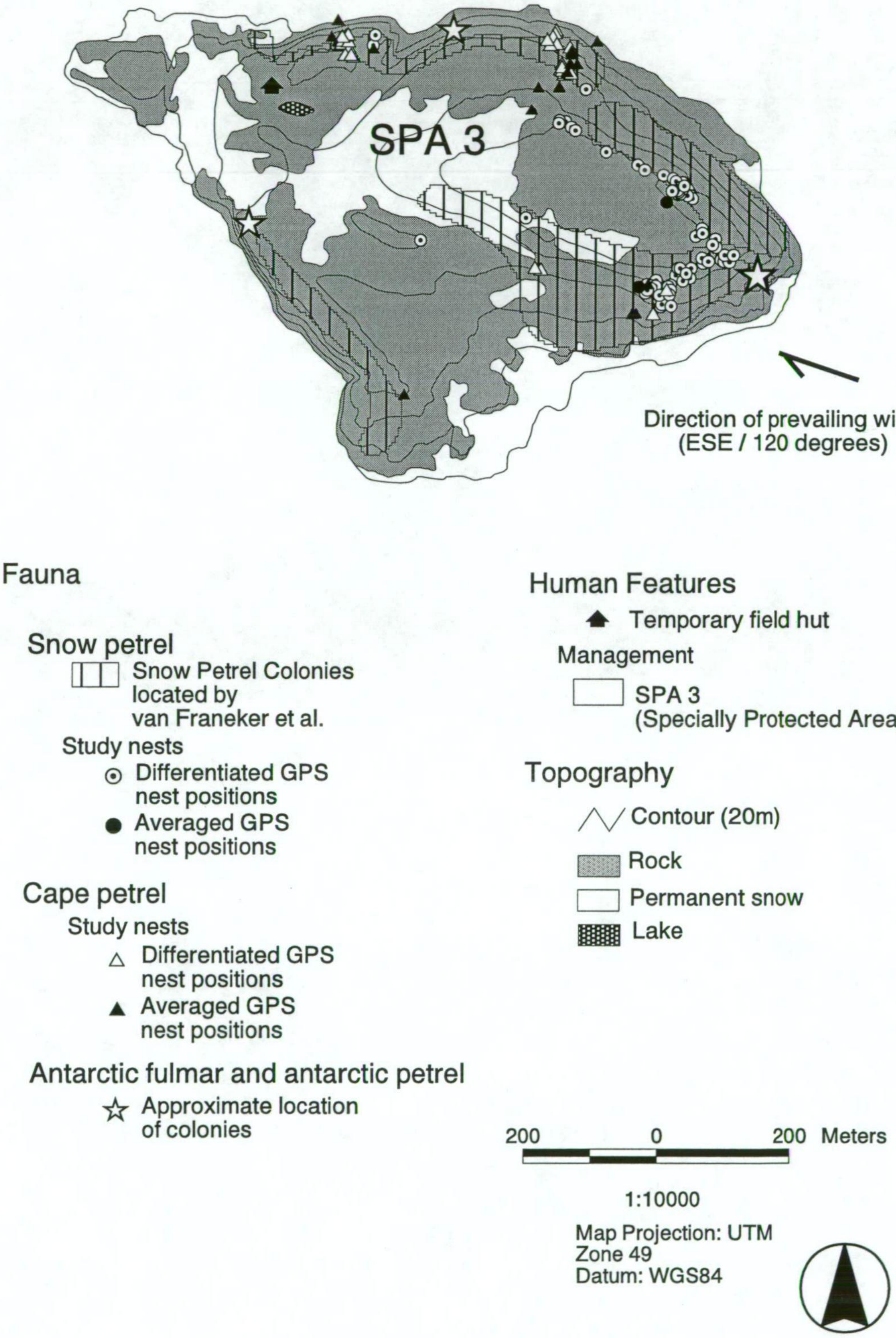


Figure 5.5: Locality map of Peterson Island.

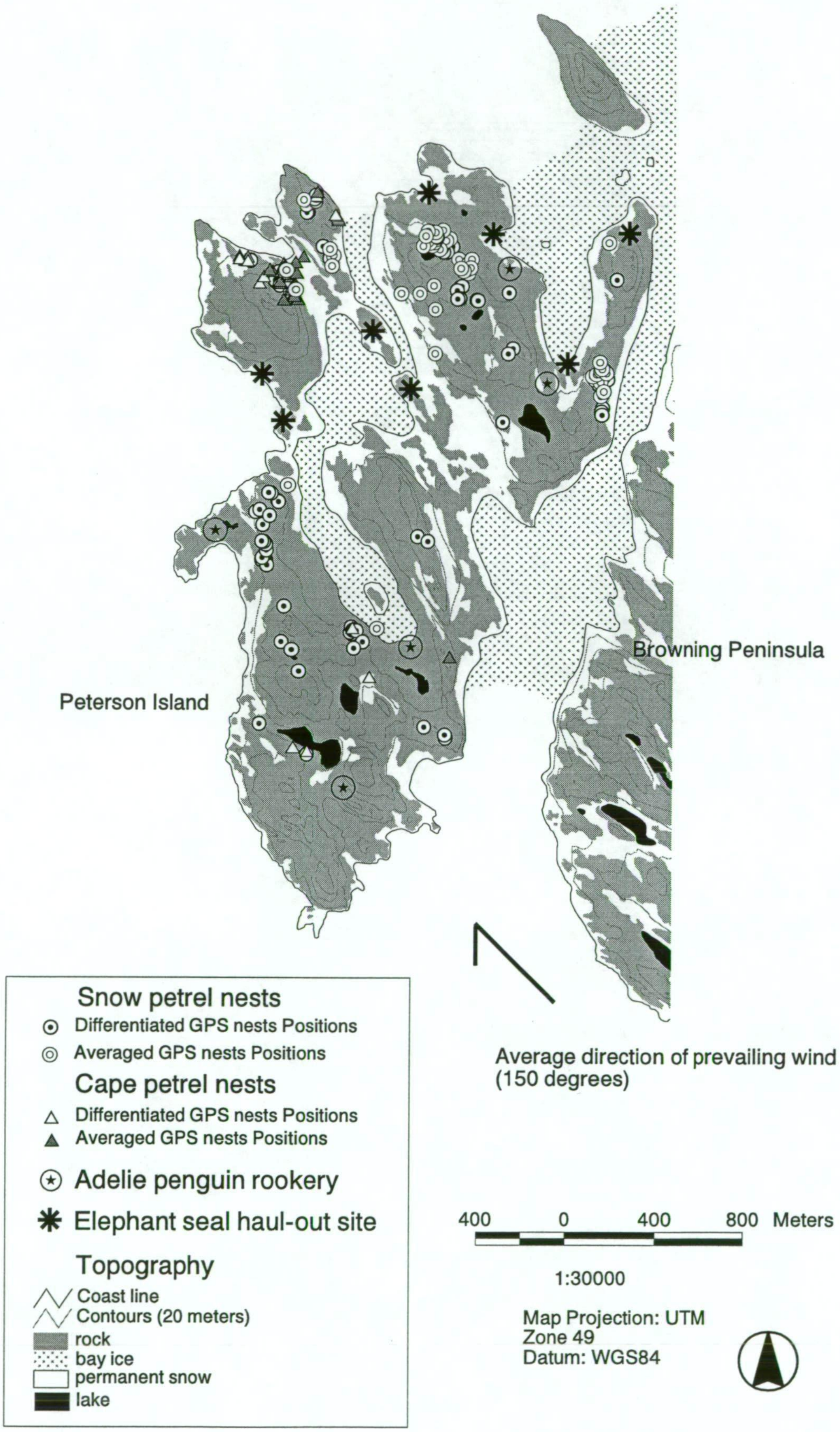


Figure 5.6: Locality map of Clark Peninsula

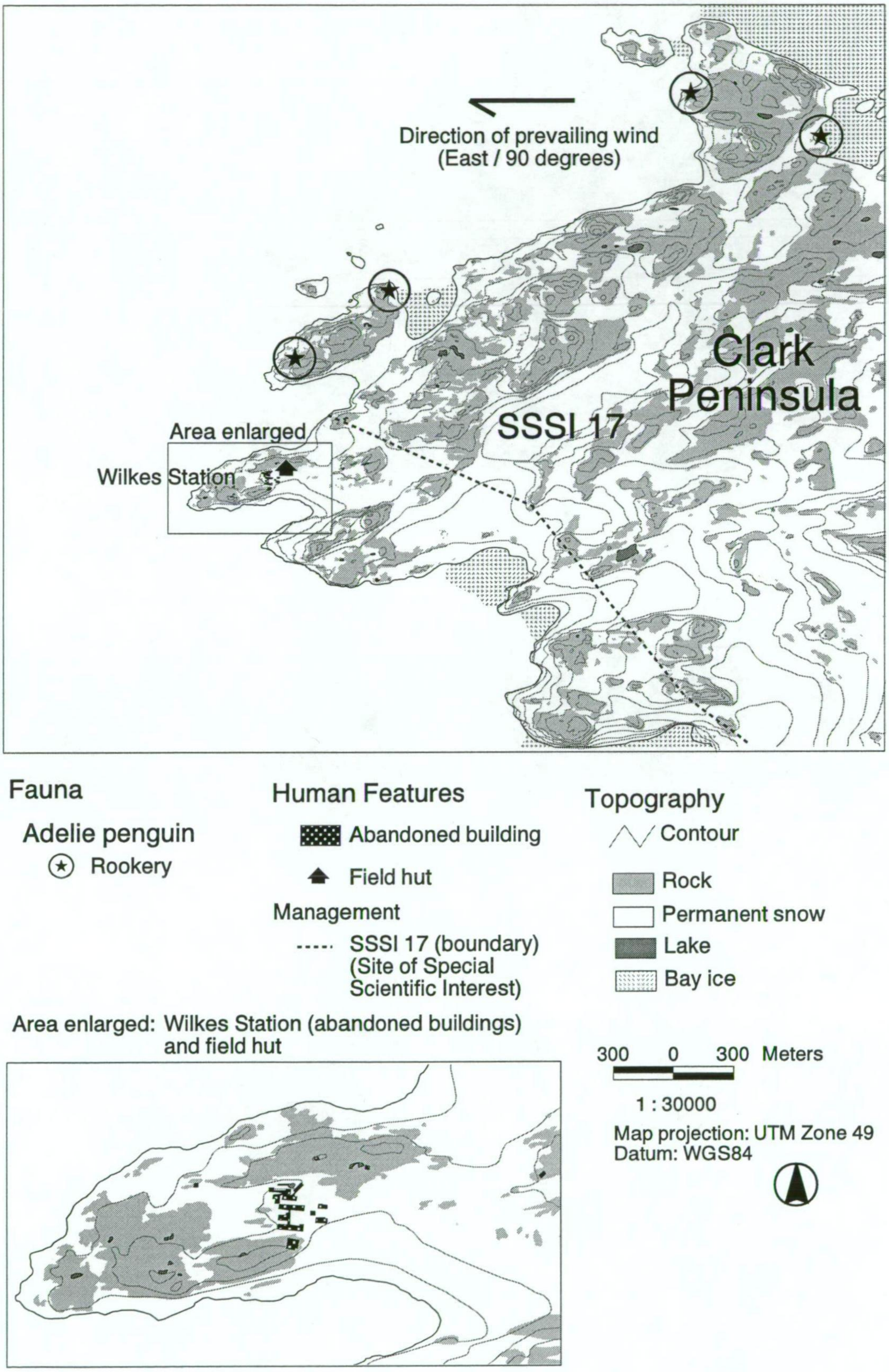
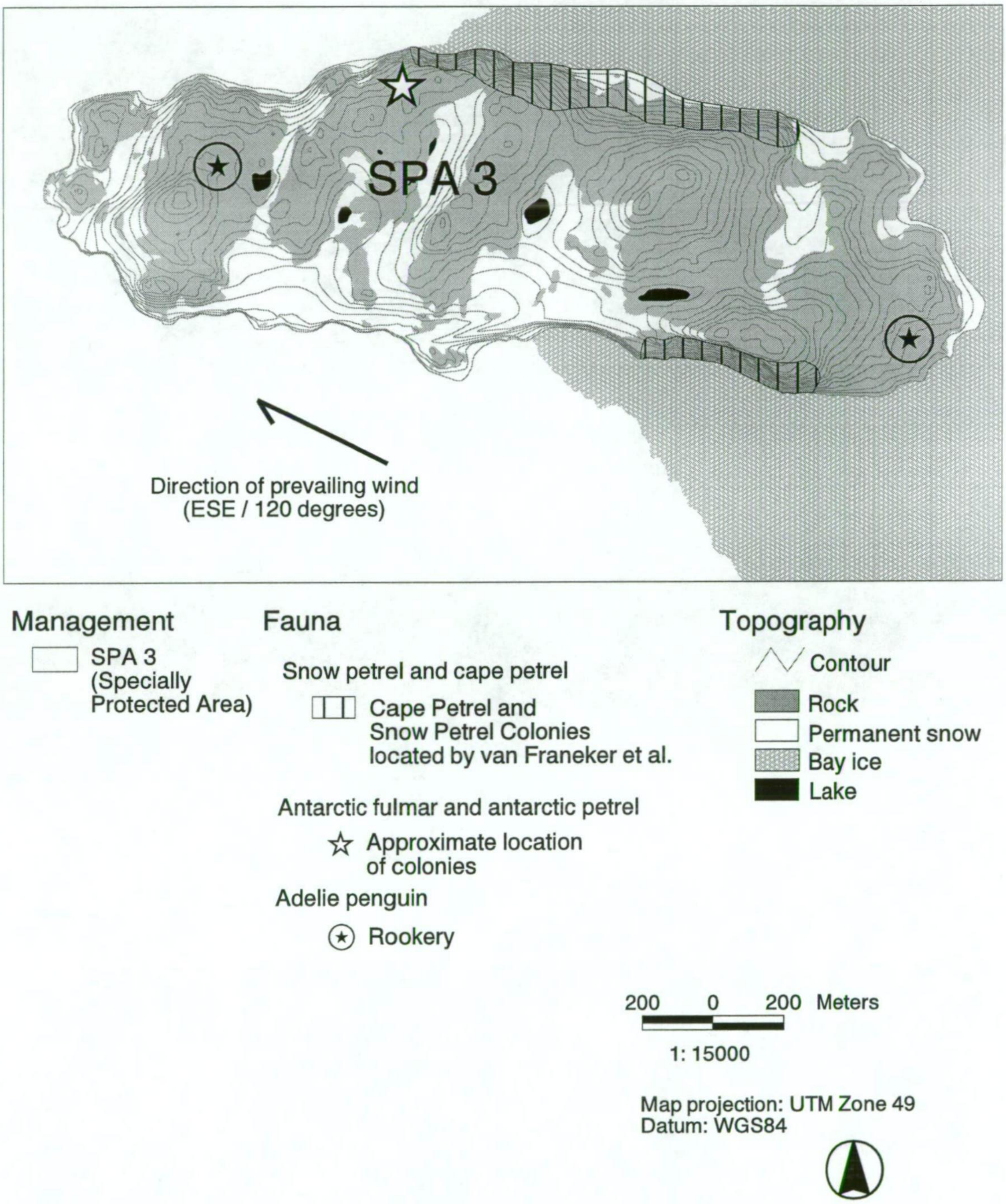


Figure 5.7: Locality map of Odbert Island



The five sites considered in this case study are given a rank within the Priority Index according to the different criteria fulfilled in order to qualify as a potential ASPA. These are: Bailey Peninsula, which contains a number of important biotic features, including an ASPA and a permanent research station (Casey); Clark Peninsula, which contains an Adelie Penguin colony and an ASPA along with the abandoned station of Wilkes with several dumping sites; Ardery, Odbert and Peterson Islands which both contain important species assemblages, Ardery and Odbert Islands being protected as ASPAs though Peterson Island has received no formal protection as yet. Despite being already designated as ASPAs, Ardery and Odbert Islands were chosen for this case study since they are important breeding site containing most of the seabird species occurring within the Windmill Islands region (with the exception of the giant petrels)[237]. This allowed comparisons with other sites to be made, particularly with respect to habitat requirements for the species considered in this case study.

2. Identification and assessment of representative sites

2.1 Definition of representativeness

The aim of representativeness is to ensure an adequate representation within protected areas of the places where species live. Smith and Theberge identify two differing definitions of representativeness, which they describe as "inclusive" and "typical" of the species present within the regional ecosystem under consideration. In the inclusive definition, "areas selected to be representative would necessarily include typical or common species but they also include rare species since their objective is to represent the range of biota"[238]. This approach views the reservation process as a means to represent the full range of natural features in a system of reserves. The alternative definition equates representativeness with typicalness. In this case, "representativeness and uniqueness can be the extremes of a spectrum. A 'unique' area is one that is rare, whereas areas which are representative are typical of a biome or habitat types"[239]. The latter definition is chosen for the case study since the uniqueness criterion is to be assessed separately (in

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[237] van Franeker, J.A.; Bell, P.J., Montague, T.L., 1990. Birds of Ardery and Odbert Islands, Windmill Islands, Antarctica, *Emu*, volume 90, pp.74-80.

[238] Smith, P., Theberge, J., 1986. A Review of Criteria for Evaluating Natural Areas, *Environmental Management*, volume 10, n°6, pp 715-734.

[239] Smith, P.; Theberge, J., op.cit, supra n° 238, p.724.

accordance with the distinctive criteria identified in Article 3.2 of Annex V).

According to the definition provided by O'Riordan, "habitat consists of both the living and the non-living components of the environment essential to the life and reproduction of the species in the area in which it lives"[240]. To meet this definition, areas selected to be representative of the Windmill Islands region must be typical of species assemblages and habitat types; they must represent the functional relationship between plants, animals and the environment. The case study is, however, restricted to the analysis of terrestrial ecosystems[241]; marine ecosystems, which are included in Article 3 paragraph 2 of Annex V, will not be considered due to the lack of available data. As O'Riordan notes:

> From an ecological point of view, a crucial difference between the sites is the way in which the process of natural succession needs to be managed. Succession is the sequence of changes that take place in plant and animal communities as they develop over a period of time in one place. These changes are responses to a changing environment, largely due to the establishment, growth, reproduction and subsequent death of the plants and animals arriving and living there[242].

Due to the limited extent of Antarctic ice-free areas, it is important to ensure the protection of sites which contain the habitat requirements of the species considered so that succession can take place. Areas fulfilling the representativeness criteria are therefore representative of the terrestrial biota present within the Windmill islands region and also representative of potential habitats for such biota. Moreover, areas selected in this case study as representative of the Windmill Islands region are relevant to the coastal ecosystem of Antarctic ice-free areas. As such, they represent a significant proportion of potential protected areas within this particular ecosystem type.
The Windmill Islands region itself is contained within a geographical and planning unit described by Keage, who proposed to establish planning units for

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240 O'Riordan, T., 1995, *Environmental Science for Environmental Management,* Harlow: Longman, Scientific & Technicalp.96.

241 The term "ecosystem" is defined as follows: "a dynamic complex of plant, animal, fungal and microorganism communities and associated non-living environment, interacting as an ecological unit". In: *Australia's Biodiversity: an Overview of Selected Significant Components,* Biodiversity Series, Paper n°2, Biodiversity Unit, Department of the Environment, Sport and Territories, Commonwealth of Australia, 1994.

242 O'Riordan, T., op.cit, supra n° 240.

natural areas in Antarctica based on geographical and ecological features: "within each unit, landforms and habitats can be identified and assessed, the richness and biological diversity of communities between areas can be compared, and threatened species can be managed"[243]. Keage's planning units are based on the major ice catchments of the Antarctic continent. The major ice catchment units proposed each have their own concentrations of ice-free land. The Windmill Islands case study area falls into Planning Unit n°IV WILKES, described as a divergent flowing ice catchment with relatively little ice-free land and with a coastline of mainly ice cliffs.

For the purpose of this case study, selected areas are representative of the Wilkes Planning Unit n°IV described by Keage since the Windmill Islands and Pointe Geologie Archipelago (where the French station of Dumont d'Urvile is located) are the only ice-free areas within the Wilkes Planning Unit n°IV. The main benefit to be gained from incorporating this approach in the selection and identification of protected areas is that the resulting protected area network recognizes ecosystem boundaries and is representative at varying geographic scales.

2.2 Criteria used to determine representativeness

The Windmill Islands region is contained within the coastal fringe of East Antarctica for which the following climatic and biotic features have been identified:

- Cold climate, with all monthly means below 0°c and means down to -15°c to -25°c in winter but some maritime influence shown in narrowing of temperature range and precipitation above 10 and often above 15 cm water equivalent.

- Bryophyte vegetation present but restricted in species and extent. Lichens and land invertebrates (notably *Acarina* and *Collembola*) numerous. Seabird colonies frequent and large: many marine mammals[244].

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[243] Keage, P., 1987, Environmental Zones and Planning Units: A Basis for an Antarctic Terrestrial Protected Area Network; In: *Conserving the Natural Heritage of the Antarctic Realm: Proceedings of the 29th Working Session of the IUCN's Commission on National Parks and Protected Areas, Wairakei, N.Z, 16-21 August 1987,* IUCN, Gland, Switzerland, pp.135-164.

[244] Holdgate, M.W., 1977, Terrestrial Ecosystems in the Antarctic, *Philosophical Transactions of the Royal Society of London. B.* 279, p.7.

Accordingly, the biotic and abiotic criteria constitutive of a representative terrestrial ecosystem for Antarctic ice-free areas are determined by the occurrence of vegetation and fauna along with their habitat requirements. Such habitat requirements coincide with key environmental parameters which are likely to determine the habitat chosen for each species under consideration. According to Holdgate, such key parameters are:

- climate: temperature, moisture, solar radiation
- terrain: altitude, aspect, slope, roughness, catchments
- geology: rock type, substrate

Classifications undertaken by biologists showed that latitude, distance from the sea, temperature and seasonal light regime were important parameters for defining habitat variations on the coastal fringe of the continent. On a smaller scale, the extent of snow-free ground in summer, altitude, slope, aspect, substrate, and soil moisture regime were recognized as important parameters[245]. These parameters may vary according to species.

2.3 Ecology and habitat requirements of snow petrels and cape petrels

(i) Ecology

The ecology of snow petrel and cape petrels described by Kamenev[246] can be summarized as follows: snow petrels spend the winter months at sea, at the ice edge and some return to their nest site in August or September for a short visit in order to clean out their nest from the snow. Couples come back for a more substantial cleaning of their nest late September before returning to sea (the pre-mating exodus). The actual court and mating occur between late October and mid-November. Snow Petrels go back to sea for approximately two weeks before coming back to their nest and laying eggs between late November and early December. The incubation of the eggs is secured by adults which in turn incubate the eggs and feed at sea. Eggs hatch in mid-January. Adults incubate the chicks all day at first, and later at night only for approximately ten days: the time required for the chicks to acquire homeothermy. Chicks are fed by parents at intervals until they fledge at the beginning of March. Most adults return to visit their nest in April before departing for winter.

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245 Holdgate, op.cit, supra n° 244, p.6.

246 Kamenev, V.M., 1988, Ecology of the Cape Pigeon and the Snow Petrel, *Polar Geography and Geology*, volume 12, n°3, pp. 227-237.

Cape petrels have a breeding biology similar to the Snow Petrels. Cape Petrels return to their nest site early October and mate during October. Eggs are laid between late November and early December. Hatching occurs during the second half of January and chicks fledge by beginning of March. Adults return regularly to their nest until April or May before departing for winter.

(ii) Habitat requirements

It is important to note that habitats of Antarctic species have not been the subject of specific studies and the information contained in the literature on this topic is scarce. While common characteristics have been outlined in the literature, habitat requirements may differ for each species. At a continental scale, the breeding distribution of Antarctic seabirds is mainly determined by substrate and climate[247]. Islands usually present a variety of nesting sites available as these areas are not heavily snow covered. Shelter from snow drift is also an important factor to consider for nest site selection of most seabirds: this parameter is however less important for snow petrels (*Pagodroma nivea*) and wilson's storm petrels (*Oceanites oceanicus*) which nest in crevices. Cape petrels (*Daption capense*), Antarctic fulmars (*Fulmarus glacialoides*) and Antarctic petrels (*Thalassoica antarctica*) have a preference for sheltered rock ledges, while giant petrels (*Macronectes giganteus*) nest in sheltered open sites[248].

Aspect can be defined as "the direction in which a slope faces, particularly with reference to possible amounts of sunshine and shadow"[249]. It appears to be an important factor for the selection of nesting sites in Antarctica as the orientation of the nest provides protection from the excesses of wind and possible obstruction of nests resulting from snow accumulation. As Stonehouse remarks: Antarctic birds tend to nest on north-facing slopes, in deep cavities, or in the shelter of cliffs and boulders away from the strongest winds, and to this degree they show sensitivity to climatic elements[250].

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[247] Croxall, J.P., 1984, Seabirds; In: (Laws, R.W., ed.) *Antarctic Ecology,* volume 2, London: Academic Press, p.548

[248] Croxall, J.P., op.cit, supra n°247, p. 547.

Murray, M.D., Luders, D.J., 1990, *Faunistic Studies at the Windmill Islands, Wilkes Land, East Antarctica,* ANARE Research Notes 73, Australian Antarctic Division.

[249] Monkhouse, F.J., op.cit, supra n° 235, p.23.

[250] Stonehouse, B., 1964, Birdlife, In: (Priestley, R., Adie, R., de Q. Robin, eds.) *Antarctic Research,* London: Butterworths, pp.219-239.

Slope appears to be an important factor influencing the selection of nesting sites, particularly for snow petrels which are nesting in screes and crevices. Screes can be defined as "slopes of angular rock debris on a mountainside of all sizes, lying at an angle of rest about 35 degrees, which remains remarkably uniform. The material is mainly formed as the result of frost action, hence it occurs most strikingly at the foot of steep rock buttresses, on which frost weathering is potent"[251]. Slope, along with aspect, is also a contributing factor to the amount and intensity of solar radiation that nests receive.

Solar radiation is referred to in the literature as a contributing factor to the breeding success of seabirds and therefore to nest quality. The accessibility of nest sites at the beginning of summer depends on the accumulation of snow and ice from the preceding winter and the degree and duration of spring melt. Beck notes that the fulmarine petrels, possessing powerful bills and claws, are able to clear their exposed nests, a process assisted by solar radiation. On the other hand, the crevice nesting species (such as the wilson's storm petrels, and to a lesser extent the snow petrels) are only capable of clearing small amounts of loose snow, but are unable to deal with ice and hard-packed snow blocking their sheltered sites[252]. The snow petrels and the cape petrels, being a group intermediate between the fulmars and the wilson's storm petrels, can be expected to rely upon solar radiation in order to facilitate the accessibility of the nests. As Chastel, Weimerskirch and Jouventin remark with respect to snow petrels: breeding success in seabirds could be significantly influenced by the location and the quality of the nest[253].
Day length may be another contributing factor to breeding sucess and nest quality. Stonehouse notes that long days would compensate for the short season in birds whose chicks are capable of rapid growth and could also help those species, possibly many of the petrels, which feed far from the nest and have to find their way back visually in overcast weather[254].

Considering the limited number of data sets available in the GIS database, the following parameters were selected as potential explanatory variables for

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[251] Monkhouse, F.J., op.cit, supra n° 235, p.321.

[252] Beck, J.R., 1970, Breeding Seasons and Moult in Some Smaller Antarctic Petrels, In: (Holdgate, M.W, eds.) *Antarctic Ecology*, volume1, London: Academic Press, pp.542-550.

[253] Chastel, O., Weimerskirch, H., Jouventin, P., 1993, High Annual Variability in Reproductive Success and Survival of an Antarctic Bird, the Snow Petrel Pagodroma nivea, *Oecologica*, volume 94, pp. 278-285.

[254] Stonehouse, B., op.cit, supra n°250.

predicting habitat suitability of two seabird species (snow petrels and cape petrels): elevation, slope, aspect, deviation to the wind and solar radiation (duration and intensity).

Snow petrels and cape petrels are selected for this case study since they are both present on Ardery, Odbert and Peterson Islands, while snow petrels also nest on Bailey Peninsula. Having different nesting patterns (snow petrels nest in crevices while cape petrels have open nests), differences in habitat requirements are hypothesized, analysed and compared between the two species in the following chapter.

3. Identification and assessment of aesthetic and wilderness sites.

3.1 Definitions

The recognition of wilderness as a value to protect in its own right has been officially recognised with the provisions contained in Article 3.2 of the Annex V of the Protocol. However the wilderness concept was legislatively acknowledged for the first time as early as the 1964 U.S Wilderness Act. In this Act, the following definition of Wilderness is provided:

> A wilderness, in contrast with those areas where man and his own works dominate the landscape, is hereby recognized as an area where the earth and its community of life are untrammeled by man, where man himself is a visitor who does not remain. An area of wilderness is further defined to mean in this act an area of undeveloped Federal land retaining its primeval character and influence, without permanent improvements or human habitation, which is protected and managed so as to preserve its natural conditions and which (1) generally appears to have been affected primarily by the forces of nature, with the imprint of man's work substantially unnoticeable; (2) has outstanding opportunities for solitude or a primitive and unconfined type of recreation; (3) has at least five thousand acres of land or is of sufficient size as to make practicable its preservation and use in an unimpaired condition; and (4) may also contain ecological, geological, or other features of scientific, educational, scenic, or historical value[255].

A similar definition of wilderness can be found in the New South Wales

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[255] Appendix A- The Wilderness Act, Public Law 88-577, 88th Congress, S.4, September 3, 1964; In: Hendee, J.C., Stankey, G.H., Lucas, R.C., 1978, *Wilderness Management*, U.S Department of Agriculture, Forest Service Miscellaneous Publication n°1365, p.82.

Wilderness Act of 1987 [256]. Both definitions are likely to be applicable to Antarctic ice-free areas except for the requirement of size. Indeed, the minimum size needed to constitute wilderness appears to be an arbitrary figure which does not coincide with wilderness conditions in Antarctic ice-free areas. As Knowles notes, the ice free part of Antarctica covers only 2 to 3 per cent of the total landmass (between 26400 and 39600 km2) and this is where most biotic life is concentrated. The most biologically rich areas are of considerably lesser extent and are dispersed over a huge continent. The smallness of some ice free areas is counterbalanced by their uniqueness. Consequently most observers would agree that they ought to be considered as wilderness[257].

According to the management plan prepared for the Tasmanian Wilderness World Heritage Area, wilderness areas have important ecological and scenic values, but neither of these qualities is unique to wilderness. The management plan emphasizes remoteness and naturalness as the two intrinsic qualities of wilderness. It refers to wilderness as follows:

> Wilderness is generally defined in recreational terms as land remote from access by mechanised vehicles and from within which there is little or no consciousness of the environmental disturbance of contemporary people[258].

As acknowledged in the management plan for the Tasmanian Wilderness World Heritage Area, even this definition of wilderness is subjective, as perceptions of remoteness and naturalness differ markedly between individuals. However, these two indicators seem the most suitable to the Antarctic context, providing they can be assessed with the GIS tools used for this study.

The relevance of wilderness protection in Antarctica, a continent already considered to be the most extensive wilderness remaining on earth, is linked to the increase in tourist activities and to the aesthetic value attached to the

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[256] Ramsay, R.; Rowe, G.C., 1995. *Environmental Law and Policy in Australia: Text and Materials,* Sydney: Butterworths, pp.603-606.

[257] Knowles, B., 1990, *The Green, White Wilderness: Applying Ecophilosophical Principles to the Management of Antarctica's Wilderness,* Centre for Environmental Studies, Department of Geography, University of Tasmania, Hobart, Australia. Unpublished Thesis (Grad. Dip. Env. St. Hons.), pp. 70.

[258] *Tasmanian Wilderness World Heritage Area Management Plan,* 1992, Department of Parks, Wildlife and Heritage, Tasmania. p.40.

wilderness concept. In this respect, expectations derived from an aesthetic value need to be identified and distinguished from the biophysical value of wilderness.

A definition of the aesthetic value of landscapes developed by the Australian Heritage Commission provides a general indication of the different aspects of aesthetic qualities to be searched for:

> The aesthetic value refers to the response derived from an experience of the environment or particular cultural and natural attributes within it. This response can be either visual or non-visual elements and can embrace emotional response, sense of place, sound, smell and any other factors having a strong impact on human thoughts, feelings, and attitudes[259].

In this case study the aesthetic value of the sites investigated is to be confined to a visual assessment of the landscape. The non-visual aspects of aesthetics will not be considered, as the attempt to embrace emotional responses to the landscape along with other factors such as sense of place, sound and smell are beyond the scope of this case study and of the analytical capabilities of GIS.

The assessment of the aesthetic quality of wilderness sites therefore provides negative values to varying degrees of visual impacts caused by human presence as an indication of alterations in aesthetic naturalness. However, Article 3.2 of Annex V suggests that aesthetic and wilderness values should be considered together as aspects of the same criterion. Therefore the overall interpretation of the aesthetic and wilderness criteria takes into account visual and biophysical impacts along with remoteness from access and settlement in the assessment of sites.

3.2 Criteria, methods and limitations of the wilderness and aesthetic assessment

To justify the criteria adopted for the identification of aesthetic and wilderness sites, it appears necessary to define the assumptions upon which these criteria are based. The following assumption appears particularly relevant to the wilderness and aesthetic qualities that visitors are likely to seek in Antarctica. It is assumed that people prefer natural to altered landscapes when visiting

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259 *Method Papers: East Gippsland and Central Highlands Joint Forests Projects, Volume 2-Cultural Values,* 1994. Australian Heritage Commission- Department of Conservation and Natural Resources, Victoria.

Antarctic ice free areas; signs of human presence thus have a negative visual impact upon the landscape.

Visual impacts can be defined as changes in available views of the landscape, and the effects of those changes on people. Visual impact assessment is therefore concerned with the intrusion or obstruction caused by human features upon views of the landscape. The Institute for Environmental Assessment and the Landscape Institute elaborated guidelines for landscape and visual impact assessment which define the aims of such procedures as follows:

In predicting visual impacts, the main requirements are to show:
- the extent of potential/theoretical visibility
- the views and viewers affected
- the degree of visual intrusion or obstruction that will occur
- the distance of the view
- the resultant impacts upon the character and quality of views[260].

These guidelines are followed in the visual impact assessment that is to be performed in this study using the spatial analysis functions of the GRID module in ARC/INFO. Each cell of the grid corresponding to the four sites considered will be used to define the altitude value of the cells for which visibility calculations are applied. Cells values are computed in relation to the type of feature selected (buildings or antennas for example) as observation points. The visibility is determined by comparing the altitude angle to the cell centre with the altitude angle to the local horizon. The local horizon is computed by considering the intervening terrain between the point of observation and the current cell centre. If the point lies above the local horizon it is considered to be visible. The output visibility grid produced will record the number of times each grid cell location can be seen by the observation points. The outcome is a map showing areas where the selected features are visible as opposed to areas from which no features can be seen. The latter ones will be given a high aesthetic value while areas for which human features are visible will be gradually classified according to the distance of each cell to the feature observed.

In the National Wilderness Inventory established by Lesslie, Abrahams and Maslen for Cape York Peninsula, in Australia, the aesthetic naturalness indicator was designed to account for the aesthetic impact that certain human

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[260] Institute of Environmental Assessment and the Landscape Institute, 1995, *Guidelines for Landscape and Visual Impact Assessment,* London: E & FN Spon, Chapman & Hall, p.48.

artefacts have on wilderness quality[261]. Values for this indicator were obtained by calculating distance to the nearest defined structure. In this case study, the GIS method used includes the effects of topography which provides in terms of visibility analysis a more accurate account of the extent of visual impacts.

The next step in the wilderness and aesthetic assessment process is to assess whether areas free of visual impacts can also be considered as pristine. The identification of pristine areas cannot rely on a visual impact assessment alone since there may be situations where various degrees of pollution could occur despite no visual alterations at a particular site.

Biophysical naturalness was defined at the beginning of this chapter as the degree to which past and current activities create human-induced environmental change and degradation to the naturalness of each site under consideration. Following this definition, an assessment of biophysical naturalness is performed. Quantitative information with respect to pollution and ecosystem disturbance is not available in the current GIS database; consequently this case study applies a qualitative assessment of sites relying upon the information available on the type of land use activity. A similar method was adopted by Lesslie, Abrahams and Maslen for the National Wilderness Inventory, as an alternative to measurements of ecosystem disturbance which were not available. In their approach, biophysical naturalness was based on the intensity of land use as an indication of the degree of disturbance sustained by an ecosystem. Instead of measuring the degree of change in ecosystems for which no data was available, the emphasis was placed on measuring the causal components of change. The assumption was that the degree of change sustained by an ecosystem was directly related to the intensity and duration of interference. The information that was used to estimate biophysical naturalness mainly relied upon land-use records[262].

In this case study, sites are to be classified according to degrees of biophysical disturbance. Three grades of biophysical disturbance are established in relation to the intensity and duration of interference resulting from land use. A high level of biophysical disturbance corresponds to accidental activities causing long term contamination or permanent destruction of habitats due to logistical, scientific or recreational activities. A medium level of biophysical disturbance corresponds to occasional interference with the fauna and flora due to logistical,

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[261] Lesslie, R., Abrahams, H., Maslen, M., op.cit, supra n°224.

[262] Lesslie, R.,Abrahams, H., Maslen,M., op.cit, supra n°224, p.14.

scientific or recreational activities. A low level of biophysical disturbance corresponds to occasional or recreational use of an area free of important species assemblages. GIS is used in order to locate areas of biophysical disturbance which will be enclosed within a grid cell and given a value corresponding to the level of biophysical disturbance.

Once the aesthetic and biophysical naturalness is assessed for the four sites under consideration an overall value can be derived for the wilderness and aesthetic criteria. It is important however to be aware of the limitations of the biophysical assessment described above. Since pristine areas are likely to coincide with areas of low level of biophysical disturbance which is characterised by an occasional use for recreational purposes, the question of long term use and their likely cumulative impacts is not considered.

Moreover, the issue of long term/cumulative recreational impacts has an important implication for the wilderness and aesthetic quality of an area and repercussions in management terms. As Buckley notes, surveys of visitors to natural areas show that they expect such areas to have little or no development. Visual impacts along with noise and crowding are perceived as nuisances. In this respect, complaints of visitors often reflect the different expectations of different groups: for instance, those who use mechanised means of transport and those who do not. However, as the number and density of visitors at a particular site increases, the characteristics of that area do change in consequence. Accordingly, the type of people visiting the area along with their expectations and requirements change over time. Those who have come to the area to enjoy wilderness pursuits based on the enjoyment of undisturbed natural environments are replaced by those who have come to enjoy sports and outdoor social activities. Visitor surveys may thus still indicate that visitors are satisfied with current conditions but they are not the same visitors[263].

The situation described above reflects the need for wilderness management in order to ensure that the natural qualities of sites are not altered over time. Considering the limited number of tourists who have visited the Windmill Islands thus far, the assessment of long term/cumulative recreational impacts may not need to be included within this case study. Moreover, such an assessment would rely upon information on the number of visitors over a number of years for each of the four site considered. Such information has not

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263 Buckley, R., 1991, *Perspectives in Environmental Management,* Springer-Verlag, Berlin-Heidelberg, p.251.

been compiled. Alternatively, pristine areas can be identified so that regulations on the intensity of use and on the type of authorised activities can be elaborated before long term recreational impacts occur.

4. Fieldwork and GIS methodology

4.1 Data collection with GPS

Data on seabirds breeding within the Windmill Islands were collected in the field during the 1995-96 summer season in order to obtain additional data sets for the GIS database. Positions of nesting sites were recorded with a Global Positioning System (GPS Magellan ProMark X) receiver. The positions recorded in the field were then downloaded to a portable computer since the GPS device could only store up to 64 positions in its memory. The latitude and longitude coordinates of the positions obtained were then differentially corrected with the GPS receiver of Casey base station in order to obtain more accurate positions. As defined in the User Guide for the Magellan GPS ProMark X:

Differential is a process that compares a dataset or subset obtained at one or more remote positions with a dataset obtained at a control (known) position, and then applies a correction to the data obtained at the remote (unknown) position. This can produce position fix accuracy of up to 2 meters RMS, depending on the geometry of the satellites used and the type of processing performed[264].

These corrections were made using Magellan Post-Processing Software. The corrected positions were then imported into the GIS database along with attributes such as date of collection and number of nests for each position recorded. Nests which were less than less 5 meters apart were recorded under the same position since no accuracy could have be gained by taking individual positions for nests separated by such a small distance. Moreover, since each grid cel can only be represented by one set of data (one GPS position along with its attributes), a second GPS position for the same grid cell would automatically become redundant. Therefore, for each GPS positions recorded, nests within 5 meters of the position recorded were included under the same position as an attribute.

Due to logistic constraints, a comprehensive survey was not possible for all of the Windmill Islands and data were recorded at known locations of colonies for

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[264] Magellan Systems Corporation, 1995, *User Guide for the Magellan GPS ProMark X*, p.3-13.

which information was incomplete. The snow petrel colony of Reeve Hill, adjacent to Casey station on Bailey Peninsula was extensively surveyed. The snow petrel, Antarctic petrel, cape petrel and fulmar colonies of Ardery Island were surveyed focusing upon the two snow petrel colonies subject to ornithological studies undertaken by Barbraud[265]. Additional snow petrel nests were recorded on the island in order to obtain a comprehensive sample of the population: each snow petrel colony was surveyed and nest positions were recorded in order to reflect the nest density of each colony. In comparison with population estimates for previous years, the number of occupied nests was considered very low. An estimate of 500 occupied nests for snow petrels was made and about 100 positions were recorded for this species. During the summer of 1986/87, van Franeker, Bell and Montague undertook an extensive survey of the distribution and number of birds on Ardery Island. Their estimation was 1000 occupied nests of snow petrels for the island[266]. During two day trips to Odbert Island, nesting sites of snow petrel, cape petrel and fulmar colonies were recorded but this survey was not comprehensive due to limited time. Small colonies of snow petrels, wilson's storm petrels and cape petrels were recorded on Peterson Island which was thoroughly investigated. A small colony of snow petrels was found on Browning Peninsula for which positions were recorded.

GPS techniques are extremely useful for establishing biotic and abiotic inventories of resources at a small scale, considering that until recently these were only roughly defined with sketch maps (with the exception of marked nests for which no GPS position had been recorded, as in the case of Reeve Hill on Bailey Peninsula). The process of collecting the data in the field is straight forward and can be performed rapidly with minimum personnel (one person usually). Additionally, data collected with GPS can be easily incorporated into a GIS database[267]. GPS techniques are currently used by several countries in Antarctica, including Australia and New Zealand. For example, the review of protected areas in McMurdo Sound undertaken by Harris of ICAIR was based

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[265] Barbraud, C., PhD Candidate, CEBAS (Centre d'Etudes Biologiques des Animaux Sauvages), Niort, France.

[266] van Franeker, J.A.; Bell, P.J., Montague, T.L., op.cit, supra n° 237.

[267] About the relevance of GPS data collection for GIS and technical issues, see for example: Erikson, C., Héroux, P., 1994, GPS Locations for GIS: Getting Them Right The First Time, In: (Power, J.M., Murray Strome, Daniel, T.C., eds.) *Proceedings Decision-Support 2001, Toronto September 12-16, 1994*, American Society for Photogrammetry and Remote Sensing, volume 1, pp.304-314.

on several GPS site visits of areas of outstanding scientific interest[268]. Biotic and abiotic inventories using GPS techniques were also undertaken in the Larsemann Hills by the Human Impacts Research Program of the Australian Antarctic Division during the summer of 1995/96.

4.2 GIS methodology

(i) Definitions of concepts used in GIS

It is beyond the scope of this research to describe the technical aspects of GIS. However, an introduction to the concepts that will be used is a preliminary requirement of the GIS application that is the case study.

The first concept that needs to be explained relates to the nature of geographical data and its representation in GIS. Geographical data are referenced to locations on the earth's surface by using a standard system of coordinates (such as latitude and longitude). Geographical data are usually recognized as well established geographical "objects" and can be reduced to three fundamental elements: points, lines and areas. A map, as defined by Burrough, "is a set of points, lines and areas that are defined both by their location in space with reference to a coordinate system and their non-spatial attributes"[269]. The second characteristic of geographical data is the attributes which describe the data. These attributes are often termed non-spatial attributes since they do not represent in themselves locational information.

In a computer-based GIS, geographical data are represented as points, lines and areas as with maps. In the ARC/INFO software system distributed by the Environmental Systems Research Institute (ESRI) that was used in this case study, the non-spatial attribute data are stored in a relational data base management system (RDBMS). The INFO system provides for the storage of spatial data while the ARC system provides for its manipulation, with individual modules for different types of function such as data entry, data editing, network analysis, and so on.

The representation of spatial data in a GIS subdivides the Earth's surface into

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[268] Forer, P., 1995, Caring for the Ice, *GIS User*, n° 10, , p.36-37.

[269] Burrough, P.A., 1986, *Principles of Geographical Information Systems for Land Resources Assessment*, Clarendon Press, Oxford, p.13.

meaningful entities or objects that can be characterised. Hence, the content of a spatial database is a model of a portion of the Earth. In a spatial data model, data can be structured in two different ways, referred to as the vector and tessellation (or raster) data models. Their respective characteristics can be described as follows: in the vector model, objects or conditions in the real world are represented by points and lines which define their boundaries as if they were being drawn on a map. The position of each object is defined by its placement on a map space that is organised by a coordinate system. In the raster model, space is regularly subdivided into cells. The location of geographic objects is defined by the row and column position of the cells they occupy. The value assigned to the cell indicates the value of the attribute it represents [270].

It is often necessary to convert datasets between vector and raster structures in order to work with the appropriate analysis tools for each data type. Star and Estes note that data could be stored in a form that both optimises geographic specificity and minimises conversion costs and attendant bias. However, this strategy is more complex than one in which all data are stored and manipulated in a single data structure[271].

In this case study, all the original data sets for the Windmill Islands that were provided by the Australian Antarctic Division, along with the GPS data collected in the field, are represented in a vector model. For example, the positions of seabirds were recorded as points, the buildings of Casey station were recorded as polygons and the topographic contours were recorded as lines. One advantage of the vector model is that it provides for the precise positioning of features in space. The common coordinate system used for all datasets was the Universal Transverse Mercator (UTM). These datasets were then converted in a raster model in order to undertake spatial analysis functions using the GRID module in the ARC system. The raster model was therefore chosen in this study because of data processing and analysis tools available for this type of data. One advantage of the raster model is that the representation of the data is more dense than in the vector model because more unique values can be stored. For example, grid cells can be provided with unique values that are computed for each variable considered as part of the habitat requirement for seabirds. On the other hand, one inconvenience of the

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[270] Aronoff, S., op.cit, supra n° 192, p.164-165.

[271] Star, J., Estes, J., 1990, *Geographic Information Systems: An Introduction,* Englewood Cliffs, NJ: Prentice Hall. p.59.

raster model is that the ability to specify a location in space is limited by the size of the raster cells, since it is not possible to know anything about different locations within a raster cell. However, because of the level of resolution chosen (5 meters), no information was lost during the conversion process with respect to nesting sites, the main focus of the study.

Topography refers to the surface characteristics, i.e. the relief, of an area. The topography of a land surface can be represented in a GIS by digital elevation data. The elevation data set represents the elevation of a large number of sample points distributed throughout the area. These sample points can be organised as a grid of points (in a raster form)[272]. This is the most common method for creating a Digital Elevation Model (DEM) which Burrough terms as "any digital representation of the continuous variation of relief over space"[273]. Contour lines which are traditionally used in cartography for representing continuous elevation data, are unsuitable for quantitative analysis in GIS. They are represented as lines (in a vector form) within GIS and are usually converted to a grid point model in order to create a DEM.

DEMs can be used to provide a number of analysis outputs. For example they can be used to produce line-of-sight maps which are used to determine visibility/invisibility from a specified viewpoint. Cells that are found to be in direct line of sight, that is to say unobstructed by cells closer to the viewpoint, are given a different value from those which are not[274]. In this case study, intervisibility will be used to determine those areas impacted visually by human structures. Other examples of DEMs analysis outputs include the computation of terrain parameters such as slope and aspect which are calculated using the elevation data of the neighboring points. Aspect can be defined as the direction that a surface faces, while slope is the rate of change in elevation and is usually expressed in degrees or in percent[275]. Aspect and slope will be used in this case study as environmental parameters to be taken into consideration for defining the habitat requirements of some species and also for predicting their occurrence.

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[272] Aronoff, S., op.cit, supra n° 192, p.216.

[273] Burrough, P.A., op.cit, supra n° 169, p.39.

[274] Burrough, P.A., op.cit, supra n° 169, p.49.

[275] Aronoff, S., op.cit, supra n° 192, p.216.

(ii) GIS methodology used in this case study

With respect to the sampling method used for the sites under consideration in this study (Bailey Peninsula, Ardery and Peterson Islands), grids of 5 metre square resolution were applied to each site using the GRID module of the GIS software (ARC/INFO). The term "resolution" can be defined as the smallest standard unit of space for which data are recorded. A five metre resolution was chosen as the most appropriate level of resolution to capture the data collected on seabirds. Because nests located within five meters of each other were recorded under the same GPS position, the grid resolution chosen was the most appropriate. Grids and DEMs for the three sites were derived from topographic contour lines following an interpolation procedure[276]. Difficulties in creating DEMs were encountered at a number of locations where surface discontinuities, such as in the presence of ice cliffs for which contours had been interconnected during the digitization stage, resulted in unrealistic elevation values. This problem was solved by deleting the connectors and re-digitizing the contours.

Two separate grids needed to be created in order to assess the significance of environmental parameters in relation to species habitat requirements. A first grid of active cells contained nesting positions for the species under consideration. A second grid of inactive cells (containing no nests) was also created. The two types of data with active and inactive cells were used to analyse the relationship between the distribution of nests and the topographic condition of sites (as will be demonstrated in the next chapter). The grid of inactive cells contained cells sampled every 50 meters within rock outcrops extended to a 20 metre buffer. This buffer corresponds to seasonal variations in snow melt which makes rock outcrops more apparent during summers of heavy melt. Because of the fluctuation in the extent of snow cover in summer, such a buffer allows more flexibility in the interpretation of the data. Areas of rock outcrops alone were selected to create a grid of inactive cells since nesting sites for seabirds only occur on rock outcrops. Therefore, areas of permanent snow or ice can not be considered in the analysis of potential habitats. Environmental parameters likely to correspond to the habitat requirements of

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[276] The term "interpolation" can be defined as the application of a mathematical model describing the relationship between data points (such as elevation values for known locations) or contours lines in order to estimate elevation values at locations for which no ground measurements are available.

For further details, see: Star,J., Estes,J., op.cit, supra n° 271.

the species under consideration were calculated for grids of active and inactive cells according to the scientific literature.

The next step involved a process entitled exploratory data analysis which will be further detailed in the presentation of the results. This process involves a preliminary interpretation of the output grids calculated for each environmental parameter considered. The output grids provided values for each specific cell, and descriptive statistics such as means, minimum and maximum values along with standard deviation. With such outputs, the data could then be grouped into classes, allowing a graphic representation of its distribution to be made. When the results of the exploratory data analysis showed significant differences between the grid values of active and inactive cells for the environmental parameter considered, the latter was kept as one explanatory variable for the habitat requirements of the species considered. Such an approach has been commonly adopted for GIS-based habitat modeling in previous case studies and has avoided sampling errors and bias[277].

(iii) Computation of environmental parameters using GIS

Aspect, slope, elevation were computed in the GRID module of ARC/INFO using the digital elevation model (DEM) created for the three sites where nests were recorded: Bailey Peninsula, Ardery and Peterson Islands. The aspect, slope, elevation and solar radiation (duration and intensity) of inactive cells were computed as well.

The duration and intensity of solar radiation were computed using the SOLARFLUX program developed by Rick and Hetrick[278] for modeling the

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[277] See for example, Pereira, J.M.C., Itami, R.M., GIS-Based Habitat Modeling Using Logistic Multiple Regression: A Study of the Mt. Graham Red Squirrel, *Photogrammetric Engineering & Remote Sensing*, Vol.57, n°11, November 1991, pp. 1475-1486.

[278] Rich, P.M, Hetrick, W.A., Saving, S.C., 1994, *Modelling Topographic Influences on Solar Radiation: A Manual for the SOLARFLUX Model*, Draft, Department of Systematics & Ecology, Environmental Studies Program and Kansas Biological Survey, University of Kansas, Lawrence, U.S.A.

For a background concerning the theory and conceptual basis for the SOLARFLUX model, see: Hetrick, W.A., Rich, P.M.., Barnes, F.J., Weis, S.B., 1993, GIS Based Solar Radiation Flux Models, In: (Lewis, A.J., ed.) *Looking to the Future with an Eye on the Past, ACSM/ASPRS Convention, New Orleans*, volume 3, pp.132-143.

For a theoretical basis of topographic solar radiation models, see: Dubayah, R., Rich, P.M., 1995, effects of topography on incoming solar radiation. As Rich et al. remark: insolation is a function of latitude, day of year, time of day, slope and aspect of the receiving surface, and horizon obstruction. Appropriate solar radiation models must therefore account for changes in solar angle with time, atmospheric effects, and topographic influences of elevation, surface orientation, and shadows. SOLARFLUX is a GIS-based program for modeling incoming solar radiation using the GRID module of ARC/INFO. A digital elevation model is inputted as surface topography and the latitude and longitude along with time interval for calculation are specified by the user. The SOLARFLUX model is assuming clear sky conditions with a transmitivity value of 1. The output is a grid of insulation values for each surface location during the specified time interval, as shown in Appendix I for Bailey Peninsula, Ardery and Peterson Island. The amount of hours and the intensity of solar radiation were computed for key days of summer: at solstice, the 31st of January when snow petrel and cape petrel chicks become thermally independent, the 1st of March when they are about to fledge and at equinox.

The deviation of the nests to the prevailing winds was derived from the computation of aspect. The deviation expresses the angle (in degrees) of each nest to the prevailing wind of the location considered. Prevailing winds were analysed from the data obtained by the Bureau of Meteorology[279] for Casey station (Bailey Peninsula) and Haupt Nunatak (located 33 kms to the south-south-east of Casey). On Bailey Peninsula, meteorological data reveals that the winds >30kts are exclusively from the East. 90 degrees was taken as the reference direction for the calculation of the deviation to the wind for Bailey Peninsula.

Haupt Nunatak is located on the edge of the Vanderfold glacier, 33Km to the SSE of Casey station. It gives an indication of the wind pattern in the South of the Windmill Islands. The meteorological characteristics of Peterson Island can be derived from the Haupt Nunatak data since the two localities are very close. Data were collected for two months during the summer 1984/85. It appears that 50% from all the winds >30kts are from the South sector, 28.3% from the East sector, 20% from the South-East sector and 1.6% from the South-West sector. An average wind direction was calculated with a direction of 146.07 degrees and

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Topographic Solar Radiation Models for GIS, *International Journal of Geographical Information Systems*, volume 9, n°4, pp. 405-419.

[279] The compilation of meteorological information was performed by Neil Adams, Senior Meteorologist at the Antarctic CRC, University of Tasmania.

rounded to 150 degrees for the reference direction of the strong winds. Ardery Island is located in the middle of the Windmill Islands and we assume that the wind direction can be averaged from the wind directions at Casey station and at Haupt Nunatak. 120 degrees is taken as the reference direction for the strong winds on Ardery Island. This is confirmed as a good approximation by the observations made in the field on both Peterson Island and Ardery Island during the summer 1995/96.

5. Conclusion

This chapter provides a methodology for developing a priority index which enables the identification of areas of biophysical and cultural significance in Antarctica. It demonstrates the relevance of using GIS in this process which could be generalized to the entire Antarctic continent providing the following conditions were met: (a) that the Antarctic treaty Parties agreed to undertake a biophysical inventory of the natural resources contained within their jurisdiction, as it is currently the case for the Australian Antarctic Territory; (b) that the CEP was responsible for the operation of the Antarctic Protected Area System through a GIS database, as suggested in chapter III of this thesis.

The following chapter will practically demonstrate the outcomes of the priority index, showing how the representative, aesthetic and wilderness values listed in Article 3 (2) of Annex V of the Protocol can be implemented in the process of identifying areas fulfilling such criteria. Because of the current limitations of the Australian Antarctic Division GIS database, criteria such as biodiversity and uniqueness along with scientific and historic values could not be assessed as part of this case study. It should be noted, however, that the methodology developed in this chapter provides the opportunity to implement such criteria providing the appropriate information was compiled into GIS data sets or formats.

Chapter VI:

The Case Study of the Windmill Islands, Wilkes Land, Antarctica:

Using GIS to develop a Priority Index for the Identification of Areas of Biophysical and Cultural Significance

Part II. Results and Discussion

1. Assessing Representativeness of Biophysical Sites

Recalling that the representative value refers to "any area identified as a representative example of major terrestrial, including glacial and aquatic, ecosystems" (article 3.2(b) of Annex V), this chapter will demonstrate how GIS can be used for the identification and assessment of coastal ecosystems likely to constitute potential habitat suitable for two species of seabirds, the snow petrel *Pagodroma nivea* and the cape petrel *Daption capense.*

The assessment of areas of habitat suitability was undertaken through the identification and computation of environmental variables considered relevant on an a priori basis as mentioned in the literature. Univariate and multivariate analysis of the data generated with GIS was then performed.

1. 1 Univariate Analysis

The aim of the univariate analysis is to identify significant variables for explaining the distribution of nesting sites on Bailey Peninsula, Ardery Island and Peterson Island. It relies on the assumption that suitable conditions exist for snow petrel and cape petrel nests and that such conditions should suit all birds irrespective of their particular location (Bailey Peninsula, Ardery Island and Peterson Island). If these two species actually select or discriminate among sites based on environmental variables identified in the literature, it should be expected that mean values of such variables differ between the locations that birds select as habitat and locations they avoid. The aim of the univariate analysis is therefore to look for common trends in the variables computed for the nesting sites of the three locations. As Chastel *et al.* [280] note, the presence of a nest does not tell us that the site represents the ideal spot for the bird. In fact, young breeding birds can spend several years looking for a suitable nesting site.

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[280] Chastel, O., Weimerskirch, H., Jouventin, P., op.cit, supra n° 253, p.283.

The univariate analysis therefore attempts to identify the characteristics of the sites shared by a maximum number of birds. In doing so, it is necessary to analyse the distribution of nests for each explanatory variable. It is assumed that if the distribution does not show any regrouping of the nests around particular values, it is likely that the variable considered is not important for the birds. On the contrary, if nests are regrouped closely around particular values, it is likely that birds are influenced by this variable when choosing a nesting site. This is particularly relevant when analysing the significance of variables with respect to northern and southern groups of birds.

It is clear that in most cases there is no or little difference in the measured variables between the nests and the inactive cells. This does not necessarily mean that the variable considered is not important for the birds since it may depend on the selection that was made of the inactive cells. The selection of inactive cells was restricted to snow- free areas and therefore the inactive cells do not reflect the topographic background in its totality. No bird will ever nest in snowed-in areas and therefore these do not represent an interest for the study. On the other hand, by limiting the choice of the inactive cells to the snow-free areas, one introduces a constraint in that the inactive cells have one parameter in common with the nesting sites: both are snow free. Consequently, one can forecast that the range of differences between the background (the inactive cells) and the nesting sites will be minor. Therefore, observed differences, even very slight, are important.

The characteristics of the three study sites also need to be discussed in order to understand any potential bias in the data. In this respect, it is important to note that differentially corrected positions for some nesting sites located in the northern part of Ardery Island could not be obtained due to an insufficient number of common satellites captured by the GPS receiver and the base station of Casey. Because of the low accuracy of the raw GPS positions these were not included in the case study. The sampling of Ardery Island therefore presents a strong bias in that it provides an over-representation of nesting sites located in the southern part of the island for which different solar radiation conditions apply.

(i) Aspect

The analysis of the results shows differences between the orientation of nests at the three sites, and between active and inactive cells as shown in Figure 6.1.

Inactive cells

At the three study sites, inactive cells are distributed from 0 to 360 degrees. However, inactive cells are not evenly distributed among all aspect classes (Figure 6.1). Inactive cells are arranged along a preferred axis and have a bimodal distribution with the two groups having opposite directions. Inactive cells have a preferential north-south orientation on Bailey Peninsula (with a peak at 330-360 degrees and one between 120 and 210 degrees) and Ardery Island (with two major groups, one from 300 to 60 degrees and one from 120 to 210 degrees); and a preferential east-west orientation on Peterson Island (with major peaks from 30 to 90 degrees and from 210 to 270 degrees).

Snow petrel nests

The aspect of snow petrel nests is not evenly distributed but shows a clear partition into two groups. At the three study sites, the two groups have average relative aspects differing by 140-150 degrees. However, there are differences in the true aspect of the groups according to the location of the study sites within the Windmill Islands. On Bailey Peninsula, in the northern part of the Windmill Island, there is a large group of snow petrel nests with an average NNE aspect (21.2 degrees) and a smaller group with an average SSE aspect (165.0 degrees). On Peterson Island, in the southern part of the Windmill Island, there is a large group of snow petrel nests with an average ENE aspect (76.3 degrees) and a smaller group with an average SW aspect (235.0 degrees). On Ardery Island, in the middle of the Windmill Island, there is one group of snow petrel nests with a NE aspect (42.9 degrees) whilst the other has a southern aspect (187.0 degrees) as shown in Table 6.1. With the exception of Ardery Island, the most northern group is the larger.

Cape petrel nests

The aspect of cape petrels nests is not evenly distributed from 0 to 360 degrees. The two groups on Ardery Island have an average aspect differing by 150 degrees. Similar to the case for snow petrels, when two groups are present in the same site, the northern group is more numerous. The groups have respectively an average NE aspect (27.9 degrees) and an average south aspect (185.6 degrees). On Peterson Island, there is only one group with an average NE aspect (52.1degrees).

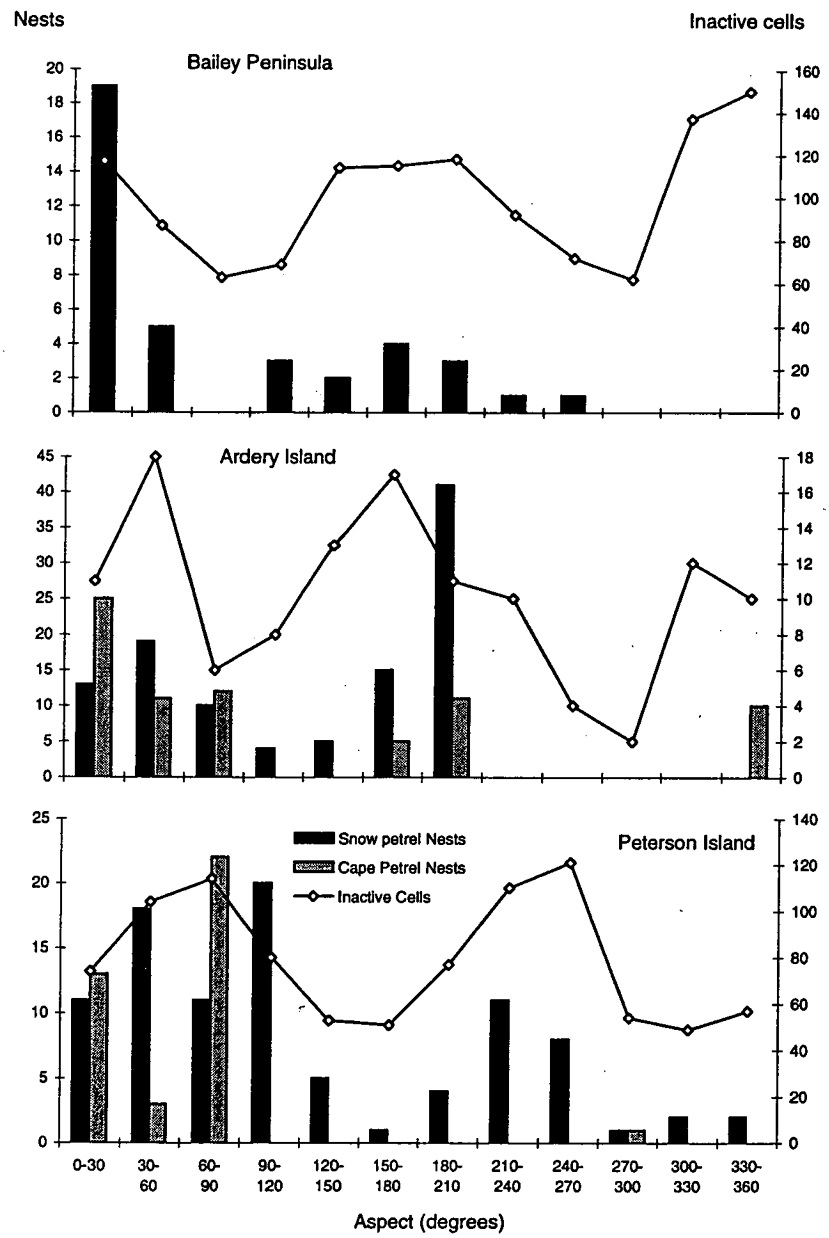

Figure 6.1: Aspect of snow petrel and cape petrel nests and inactive cells

Table 6.1: Aspect (mean ± standard deviation) of the snow petrel and cape petrel groups of the three study sites.

Species	Location	Aspect (Degrees)	
		N/N-E group	S/S-W group
Snow petrels	Bailey P.	21.2 ±6.2	165.0 ±41.6
	Ardery Isl.	42.9 ±22.1	187.0 ±13.3
	Peterson Isl.	76.3 ±39.4	235.0 ±21.6
Cape petrels	Ardery Isl.	27.9 ±29.2	185.6 ±14.4
	Peterson Isl.	52.1 ±27.9	_

(ii) Prevailing winds

This factor was assessed by calculating the deviation of the nests to the prevailing winds. The deviation of the nest orientation to the prevailing winds was derived from the nests aspect. The deviation is expressed as an angle in degrees from 0 to 180 degrees. 0 degrees of deviation to the wind means that the nest is facing the wind. On the other hand, 180 degrees of deviation to the wind means that the nest is opposite the wind, whereas 90 degrees of deviation means that the nest is at a right angle to the wind, on the left or on the right.

Inactive cells

On Bailey Peninsula, the inactive cells have a bell shaped distribution with a maximum in the class 90-120 degrees (Figure 6.2). On Ardery Island, the inactive cells have a distribution with a maximum in the class 60-90. On Peterson Island, the distribution of the inactive cells has a symmetric curve showing a maximum between 60 and 120 degrees.

Snow petrel nests

The distribution of the deviation of the snow petrel nests to the prevailing wind shows a bell shaped distribution in the three study sites (Figure 6.2). The distribution is predominant on the windward and right-angle-to-the-wind sectors (i.e. from 0 to 120 degrees) on Bailey Peninsula[281] and Ardery Island[282].

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[281]Meteorological data for Casey station, located on Bailey Peninsula, show that strong wind

On Peterson Island[283], the nests are present from 0 to 180 degrees. There are similarities in the distribution of the northern and southern groups for each of the sites. The groups have an average deviation to the wind between 62.7 degrees (Southern group of Ardery Island) and 86.1 degrees (northern group of Peterson Island) as shown in Table 6.2. The nests are grouped in classes ranging from 30 to 120 degrees to the wind since this sector regroups between 64 per cent (southern group of Bailey Peninsula) and 100 per cent of the nests (southern group of Bailey Peninsula).

Table 6.2: Deviation in degrees (mean ± standard deviation) of snow petrel nests from the prevailing winds for each group.

	Snow Petrels		
	Bailey Peninsula	Ardery Island	Peterson Island
Northern group	68.8 ±12.2	71.7±27.1	86.1 ±33.8
Southern group	75.0 ±43.9	62.7 ±19.1	82.2 ±39.5
Total	71.5 ±28.5	66.6 ±23.5	83.3 ±38.0

Cape petrel nests

The cape petrel nests of Ardery and Peterson islands are distributed from 30 to 150 degrees to the prevailing winds (Figure 6.3). There is no cape petrel nest in the windward (0-30 degrees) or the leeward 150-180 degrees sectors. The cape petrel nests, with the exception of the southern group of Ardery Island, have an average deviation to the wind between 92.1 and 98.8 degrees respectively for the northern group of Ardery Island and the northern group of Peterson Island as shown in Table 6.3. The southern group of Ardery Island is much closer to the wind with an average deviation to the wind of 70.0 degrees. A statistical test of significance (or Z test) was performed for the two population means (the Northern and Southern groups)based on samples[284]

events (> 30km/h) are overwhelmingly from the east. See footnote n° 279.

282 The prevailing wind on Ardery Island is estimated coming from 120 degrees in accordance with the information provided by the Bureau of Meteorology (see footnote n° 279).

283 The prevailing wind on Peterson Island is estimated coming from 150 degrees in accordance with the information provided by the Bureau of Meteorology (see footnote n° 279).

284 For further details concerning this method see: Zar, J.H., 1996, *Biostatistical Analysis*, Third Edition, N.J: Prentice Hall.

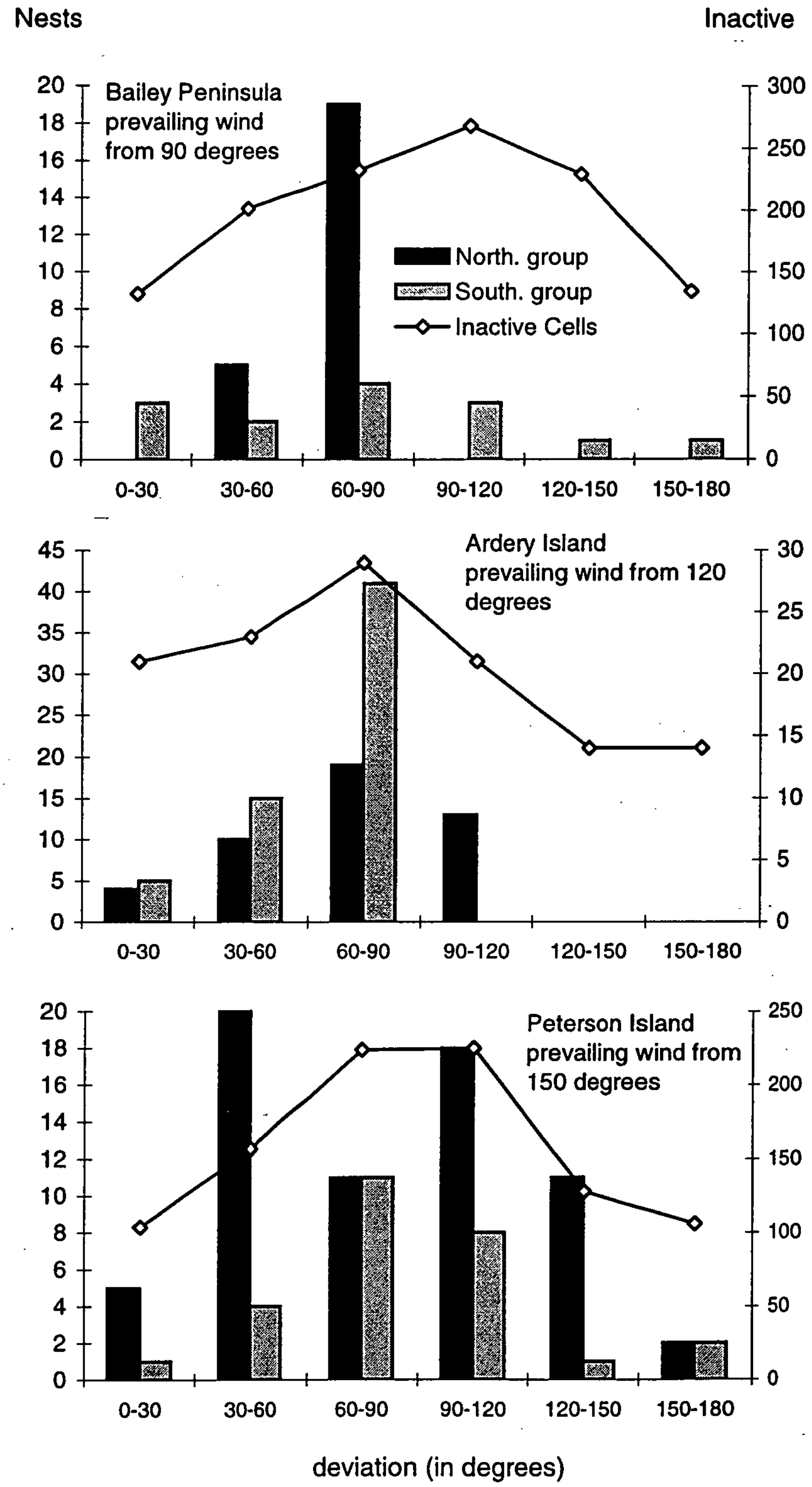

Figure 6.2: Deviation of snow petrel nests and inactive cells from prevailing winds

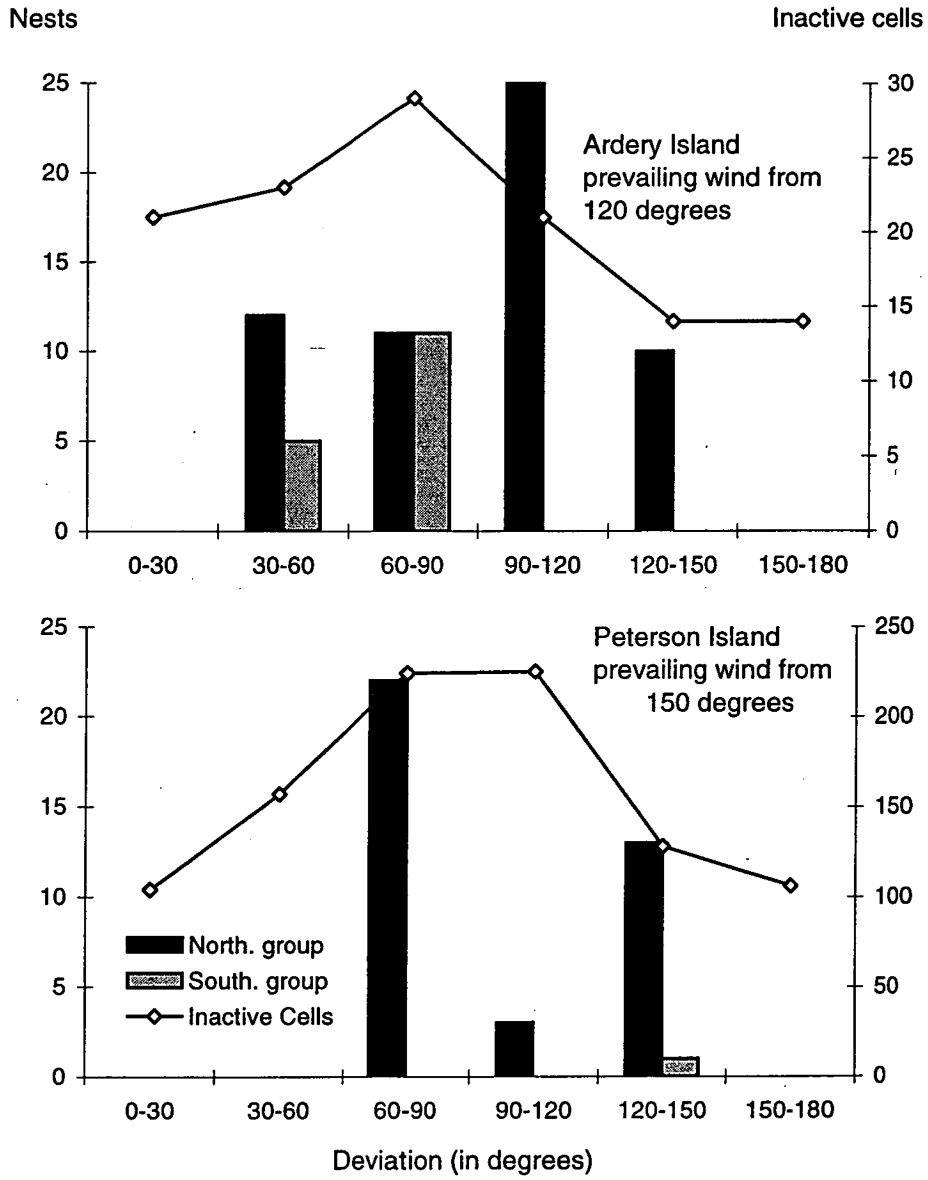

Figure 6.3: Deviation of cape petrel nests and inactive cells from the prevailing winds

When Z > 2.0, the difference observed is considered significant, in other words the null hypothesis that states that the mean wind deviation is the same for the northern and southern group is rejected. In this case the result is presented as follows: $Z = 2.99$; $P < 0.05$.

Table 6.3: Deviation in degrees (mean ± standard deviation) of cape petrel nests from the prevailing winds for each group.

	Cape Petrels	
	Ardery Island	Peterson Island
Northern group	92.1 ±30.1	98.8 ±28.2
Southern group	70.0 ±25.0	-
Total	86.3 ±29.5	98.8 ±28.2

(iii) Slope

Inactive cells

The slope of inactive cells reflects the topographic conditions of the three sites. Bailey Peninsula is a plateau with Reeve Hill being the predominant hill in the area. Consequently, the slope of inactive cells on Bailey Peninsula ranges from 0 to 50 degrees, with 79 per cent of the inactive cells in the single class 0-10 degrees (Figure 6.4). The mean value of slope for the inactive cells is 6.9 ±5.8 degrees. Ardery Island has high elevation values (up to 120 meters for the inactive cells) and two main plateau surrounded by cliffs. The slope of inactive cells on Ardery Island ranges from 0 to 70 degrees, with a majority of cells (60.6%) from 0 to 20 degrees. The mean value of inactive cells is 22.3 ±17.4 degrees. Peterson Island is composed of hills with flat areas at the centre which can be subject to floods in summer during the snow melt. The slope of inactive cells on Peterson Island ranges from 0 to 60 degrees, the majority of cells (89.9%) being contained between 0 to 30 degrees. The most numerous class is at 0-10, with 41.5 per cent of the inactive cells. The mean value of slope for the inactive cells is 14.4 ±11.1 degrees.

Snow petrels

The average slope of the snow petrel nests is greater than adjacent inactive cells and ranges from 19 to 30 degrees. The slope of the snow petrel nests ranges for

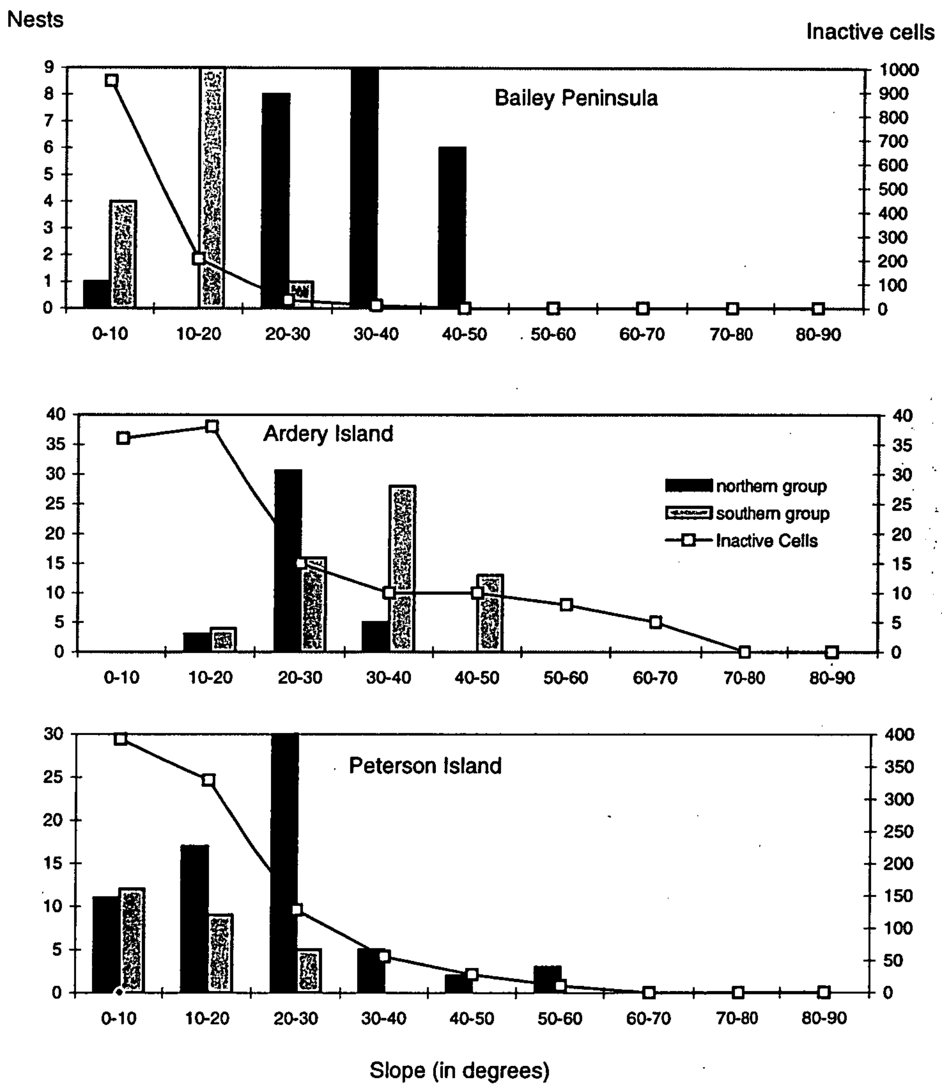

Figure 6.4 : Slope of snow petrel nests and inactive cells

the whole Windmill Islands from the class 0-10 to the class 50-60 degrees respectively on Bailey Peninsula and Peterson Island. The differences of the average values of slope for the snow petrels at the three sites indicate that the snow petrels select their nest sites over a wide range of slope; however, they preferentially select sites with 20-30 degrees of slope since this class is the best represented in the three sites. Tests of statistical significance (Z tests) show that the differences of slope between the snow petrel groups and the inactive cells are all significant[285], except for the northern group of snow petrel and the inactive cells of Ardery island ($Z = 1.5$; $P > 0.05$).

Cape petrels

The average slope for the cape petrel nests is steeper than for the snow petrel nests on Peterson Island whereas it is similar for both species on Ardery Island. The results of the Z test show that the difference of slope between the Northern groups of snow petrel and cape petrel nests on Peterson Island is statistically significant ($Z = 5.29$, $P < 0.05$). Similarly the difference between the southern group of snow petrel nests and the northern group of cape petrel nests on Peterson Island is significant ($Z = 10$, $P < 0.05$). The most numerous class is at 30-40 degrees on Ardery Island whereas it is at 40-50 degrees on Peterson Island. Contrary to snow petrels, cape petrels avoid sites with less than 10 degrees of slope.

Table 6.4: Slope in degrees (mean ± standard deviation) of snow petrel and cape petrel nests and inactive cells at the three sites.

	Bailey Peninsula	Ardery island	Peterson island
Snow petrels			
northern group	31.8 ± 9.9	25.0 ± 5.0	21.8 ± 11.7
southern group	12.1 ± 5.7	33.1 ± 7.3	11.6 ± 2.9
Cape petrels			
northern group		30.1 ± 9.8	36.5 ± 14.8
southern group		31.8 ± 7.9	
Inactive cells	6.9 ± 5.8	22.3 ± 17.4	14.4 ± 11.1

[285] The results are: $Z = 12.38$; $P < 0.05$ for the inactive cells and the northern group of snow petrel nests onBailey Peninsula; $Z = 3.37$; $P <0.05$ for the inactive cells and the southern group of snow petrel nests on Bailey Peninsula; $Z = 10.96$; $P < 0.05$ for the inactive cells and the southern group of snow petrel nests on Ardery Island; $Z = 5.8$; $P < 0.05$ for the inactive cells and the northern group of snow petrel on Peterson Island; $Z = 3.88$; $P < 0.05$ for the inactive cells and the southern group of snow petrel nests on Peterson Island.

(iv) Elevation

Inactive cells

On Bailey Peninsula the inactive cells range from 0 to 70 metres of elevation, however the majority of cells (68%) range from 20 to 50 metres. The most numerous class is at 30-40 metres, with 37 per cent of the inactive cells. The mean elevation value for the inactive cells is 28 ±14 (sd) metres. On Ardery Island, the inactive cells range from 0 to 120 metres of elevation, but have bimodal peaks in the classes 30-40 and 50-60 metres. The most numerous class is at 50-60 metres, with 25 cells (20%). The mean elevation for the inactive cells is 52 ±25 (sd) metres. On Peterson Island, the inactive cells range from 0 to 80 metres of elevation. The majority of cells are contained within 0 to 50 metres, with 853 cells or 90 per cent. The most numerous cells are present within the single class 10-20 meters, with 226 nests or 23.9 per cent. The mean elevation value of the inactive cells is 26 ± 16 (sd) metres.

Snow petrels

The snow petrel nests have an average elevation higher than adjacent inactive cells. Results of the Z test show that the differences of elevation between the snow petrel groups and the inactive cells are all statistically significant for the three sites[286]. Snow petrels select their nesting sites in elevated areas within a given locality. The distribution ranges from a minimum of 10-20 meters on Peterson Island to 100-110 metres on Ardery Island. There is a lower limit of 10 meters above sea level for the selection of a nesting site.

Cape petrels

The cape petrel nests have an average elevation which is much lower than the snow petrel nests, although the lower limit of 10 metres above sea level for the selection of a nesting site is similar to snow petrels. Results of the Z test show

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[286] The results are: $Z = 6.06$; $P < 0.05$ for the inactive cells and the northern group of snow petrel nests on Bailey Peninsula; $Z = 11.33$; $P < 0.05$ for the inactive cells and the southern group of snow petrel nests on Bailey Peninsula; $Z = 13.26$; $P < 0.05$ for the inactive cells and the northern group of snow petrel nests on Ardery island; $Z = 10.1$; $P < 0.05$ for the inactive cells and the southern group of snow petrel nests on Ardery island; $Z = 4.72$; $P < 0.05$ for the inactive cells and the northern group of snow petrel nests on Peterson Island; $Z = 7.44$; $P < 0.05$ for the inactive cells and the southern group of snow petrel nests on Peterson Island.

that the differences of elevation between groups of snow petrel and cape petrel nests on Ardery Island and Peterson Island are all statistically significant[287]. The elevation appears to be a threshold response type of variable for both species since they have a common lower limit of 10 metres.

Table 6.5: Elevation in meters (mean ± standard deviation) of snow petrel and cape petrel nests and inactive cells at the three sites.

	Bailey Peninsula	Ardery island	Peterson island
Snow petrels			
northern group	34.5 ± 4.6	91.1 ± 12.1	32.3 ± 10.1
southern group	38.9 ± 3.2	80.8 ± 12.8	30.7 ± 1.5
Cape petrels			
northern group	_	57.5 ± 12.1	20.2 ±7.6
southern group	_	64.3 ± 7.9	_
Inactive cells	28.2 ± 14	52.3 ± 25.6	26 ± 16.6

(i) Duration of solar radiation

Values for the duration of solar radiation derived from the SOLARFLUX program for snow petrel and cape petrel nests along with inactive cells are analysed below :

Inactive cells

The inactive cells of Bailey Peninsula have the highest duration of solar radiation at the four dates. They receive two hours more than the inactive cells of Ardery Island at day 355 and day 31. This difference increases from two to three hours between day 31 and day 80. Inactive cells of Bailey Peninsula receive 1.6 hours more than the inactive cells of Peterson Island at day 355 and this difference gradually increases to 1.95 hours at day 80. Inactive cells of Ardery and Peterson islands receive approximately the same duration of solar radiation at day 355 and at day 31, then the inactive cells of Peterson Island receive 0.55 hours more at day 61 and one hour more at day 80.

[287] The results are: $Z = 5.8$; $P < 0.05$ for the northern groups of cape petrel and snow petrel nests on Ardery Island; $Z = 6.4$; $P < 0.05$ for the southern groups of snow petrel and cape petrel nests on Ardery island; $Z = 6.9$; $P < 0.05$ for the northern groups of cape petrel and snow petrel nests on Peterson Island; $Z = 7.8$; $P < 0.05$ for the northern group of cape petrel and the southern group of snow petrel nests on Peterson Island.

<u>Snow petrels and cape petrels</u>

Nests are distributed within two distinct groups which coincide with the northern and southern groups identifed in the analysis of aspect (Figures 6.5, 6.6, 6.7, 6.8, 6.9). As shown in Table 6.6 and in figures 6.5 - 6.9, the duration of solar radiation gradually decreases for all groups from day 355 to day 80. The northern groups have smaller values of duration at Day 355 than the southern groups at all sites and for both species. On Ardery Island, the northern groups of snow petrels and cape petrels receive higher duration values than the southern groups from the 1st of March. The southern groups of both species on Ardery Island have the most important variations of duration of all groups since their means decrease from 22.0 ±0.2 hours (day 355) to 1.9 ±2.8 hours (day 80) for the snow petrels and from 21.5 ± 0.7 (day 355) to 2.0 ± 0.8 (day 80) for the cape petrels.

Table 6.6: Duration of solar radiation in hours (mean ± standard deviation) for snow petrel and cape petrel nests and inactive cells at the three sites.

	Snow petrels		Cape petrels		Inactive cells
	N.group	S.group	N.group	S.group	
Bailey Peninsula					
day 355	14.9 ± 1.8	21.4 ± 0.8	_	_	19.5 ± 2.03
day 31	13.9 ± 1.3	17.4 ± 0.9	_	_	16.7 ± 1.1
day 61	12.3 ± 0.6	13.6 ± 0.6	_	_	13.3 ± 0.7
day 80	11.0 ± 0.6	10.8 ± 2.0	_	_	11.2 ± 0.9
Ardery island					
day 355	15.3 ± 1.7	22.0 ± 0.2	14.8 ± 1.4	21.5 ± 0.7	17.5 ± 3.6
day 31	14.1 ± 1.0	15.3 ± 3.0	13.9 ± 1.3	16.0 ± 2.6	14.7 ± 2.8
day 61	11.5 ± 0.8	6.1 ± 3.8	12.1 ± 1.2	7.2 ± 2.6	10.9 ± 2.9
day 80	10.1 ± 1.0	1.9 ± 2.8	11.0 ± 1.1	2.0 ± 0.8	8.1 ± 3.4
Peterson island					
day 355	16. 3 ± 2.7	19.8 ± 0.2	13.6 ± 1.5	_	17.4 ± 2.5
day 31	14.3 ± 1.9	16.4 ± 0.7	12.1 ± 1.7	_	14.8 ± 2.0
day 61	11.4 ± 1.7	12.4 ± 0.9	10.3 ± 1.5	_	11.4 ± 1.9
day 80	9.5 ± 1.5	9.8 ± 0.8	9.2 ± 1.5	_	9.2 ± 2.0

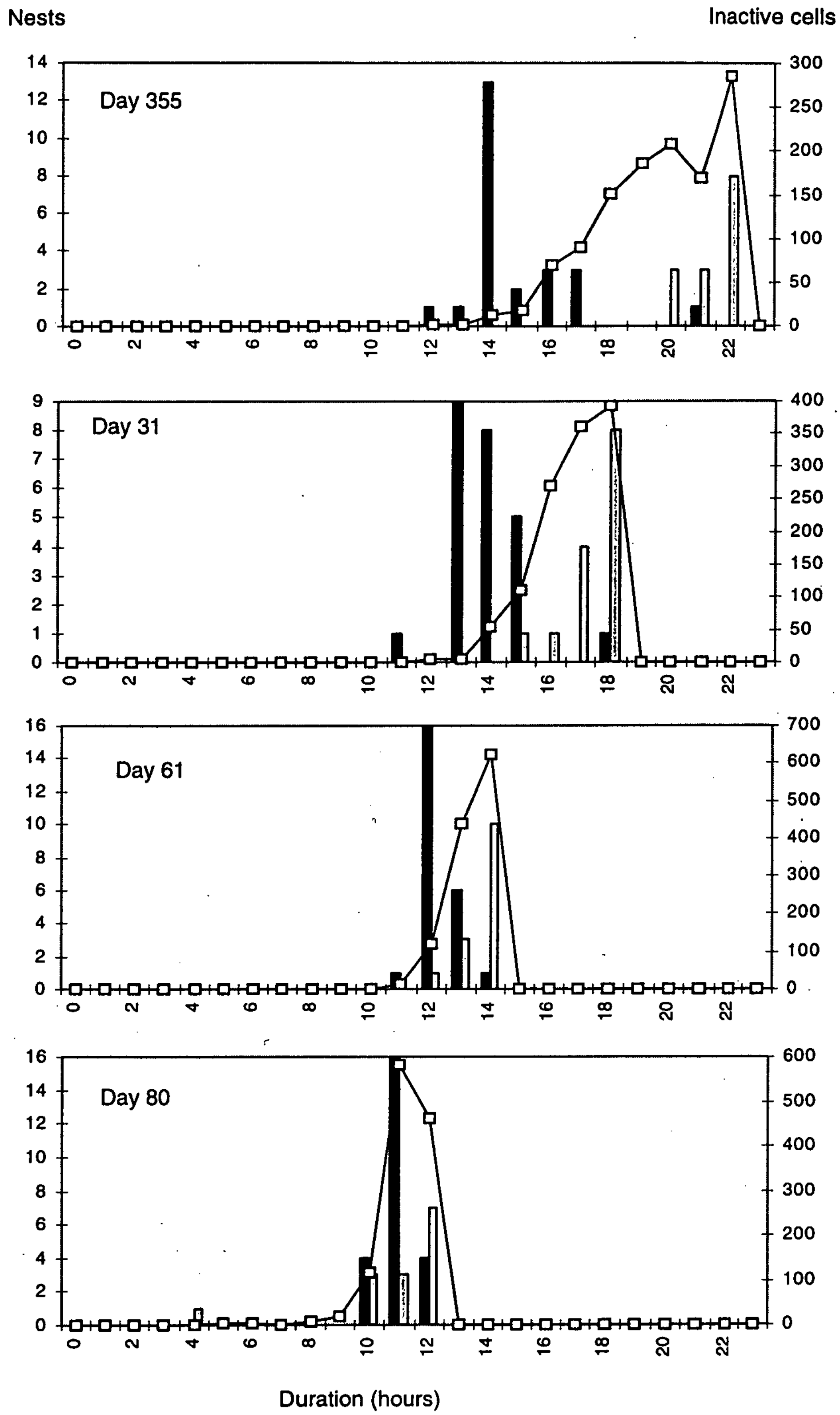

Figure 6.5 : Duration of solar radiation for snow petrel nests and inactive cells on Bailey Peninsula

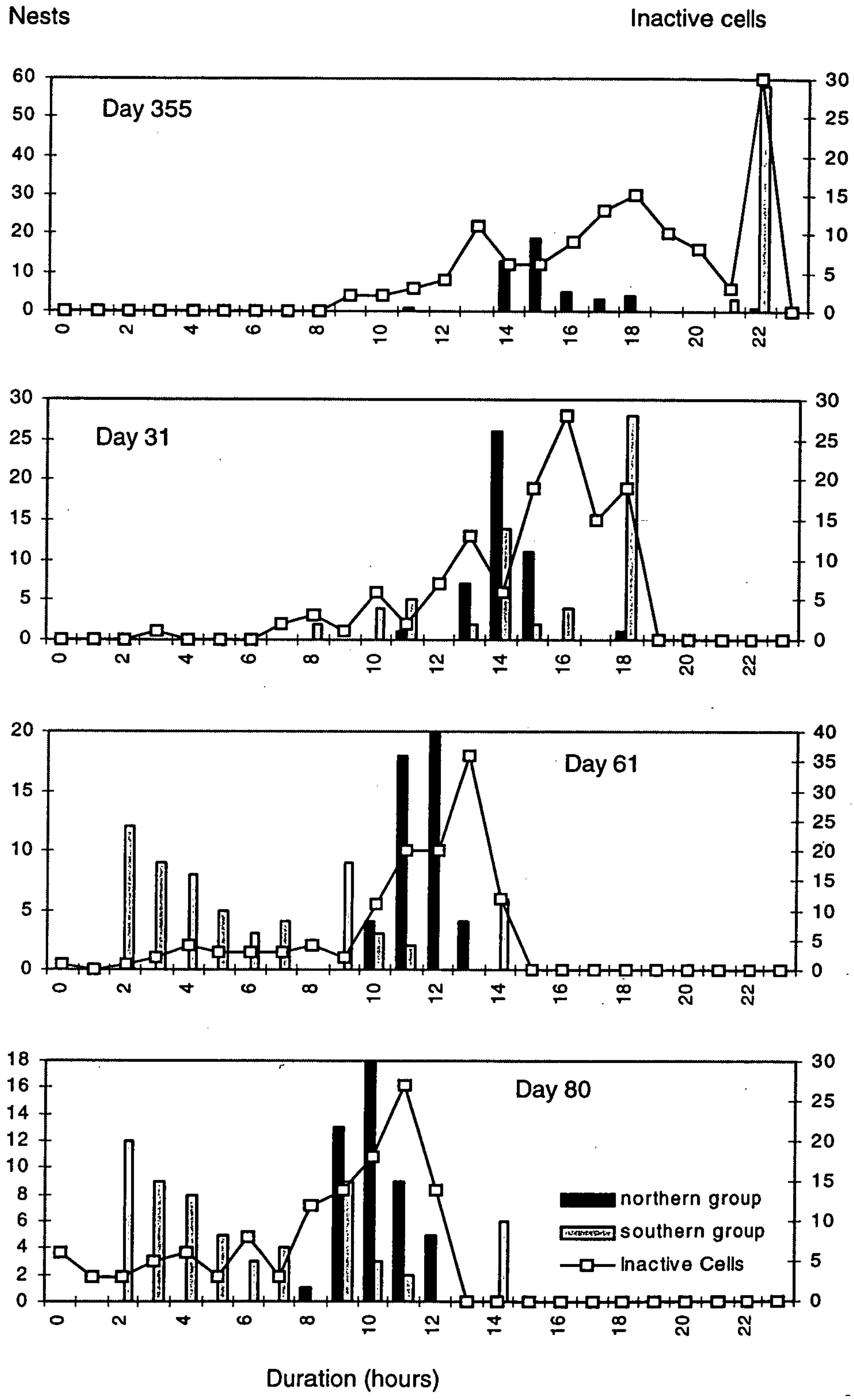

Figure 6.6: Duration of solar radiation for snow petrel nests and inactive cells on Ardery Island

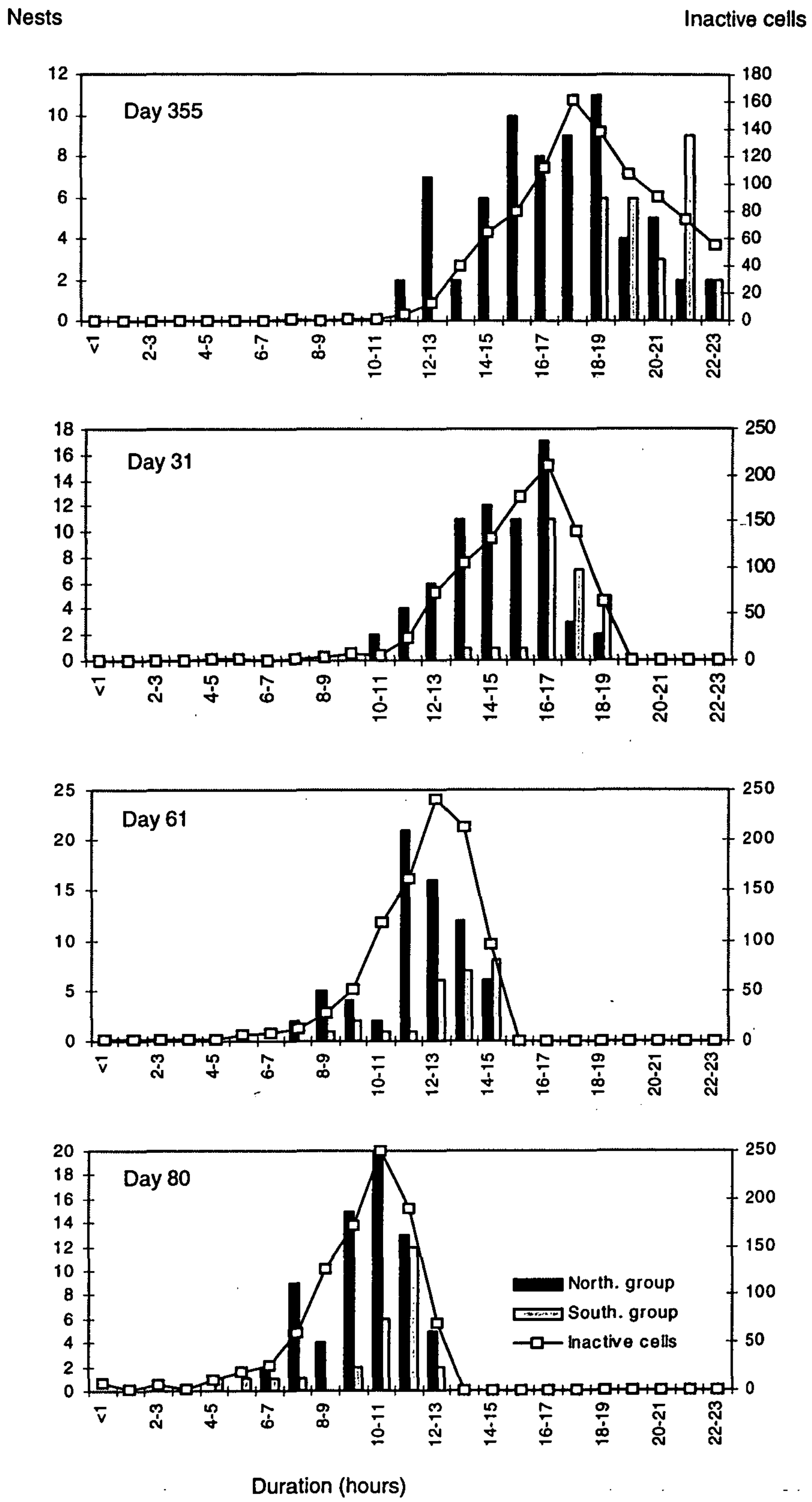

Figure 6.7: Duration of solar radiation for snow petrel nests and inactive cells on Peterson Island.

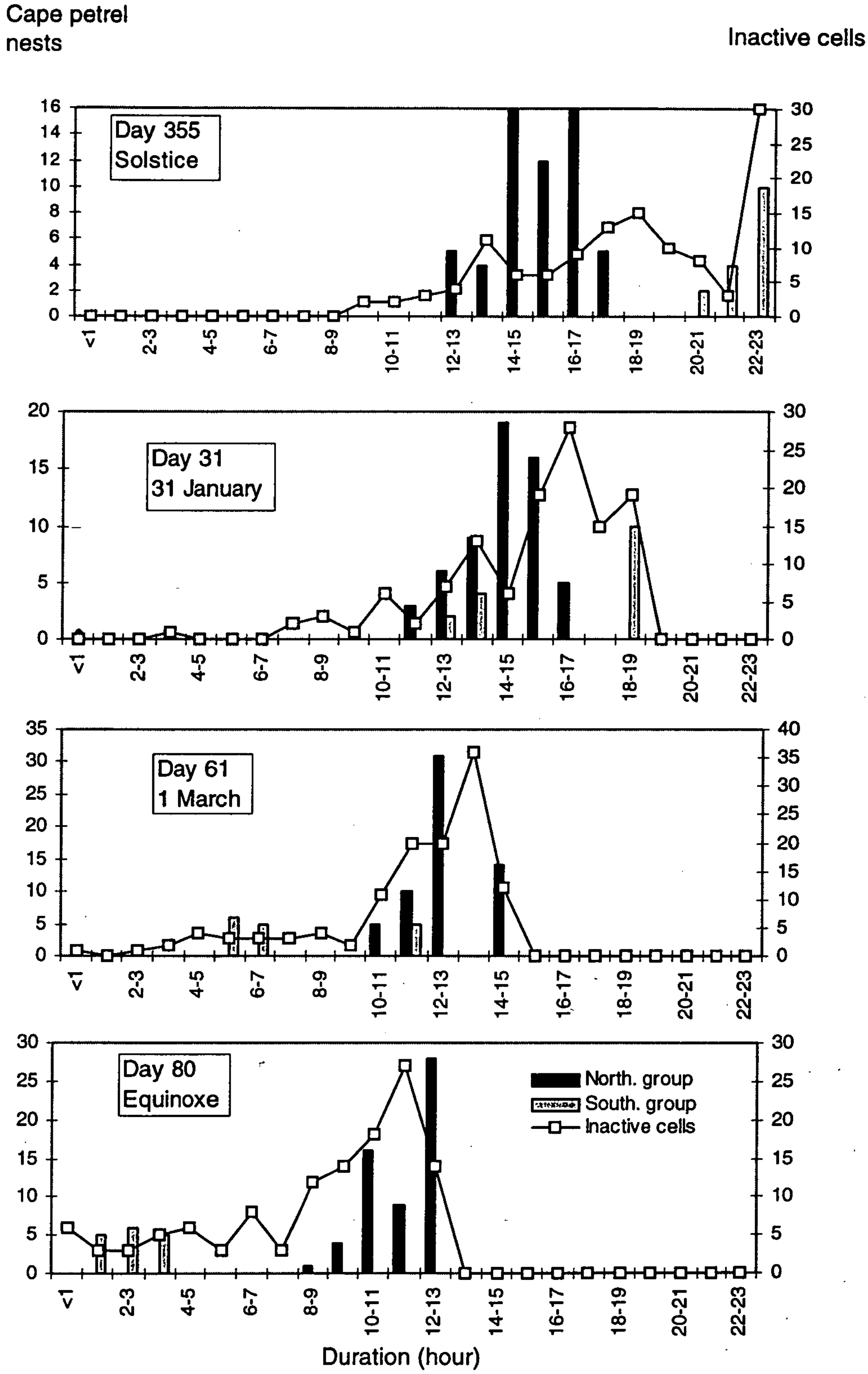

Figure 6.8: Duration of solar radiation for the cape petrel nests and inactive cells on Ardery Island.

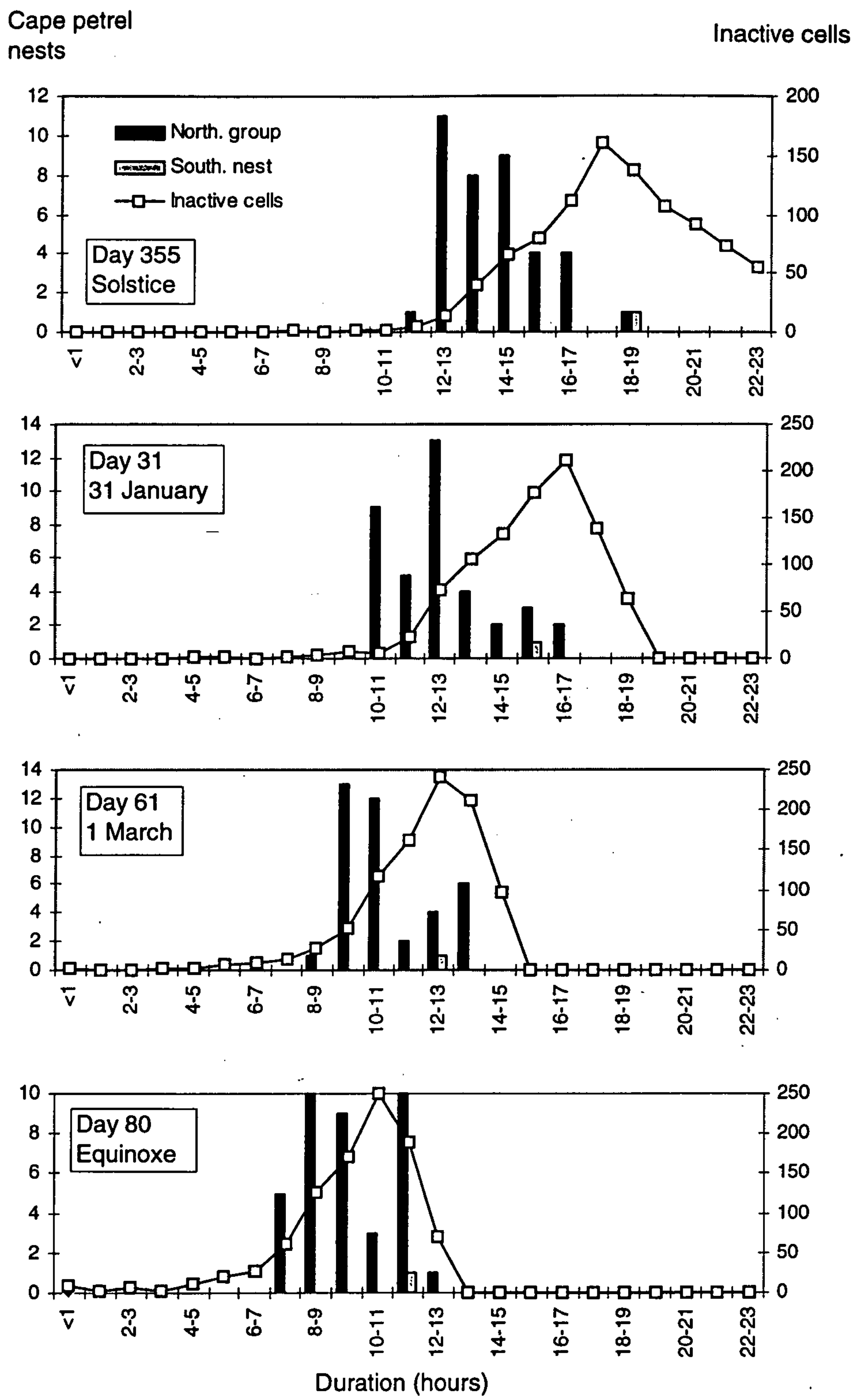

Figure 6.9: Duration of solar radiation for the cape petrel nests and inactive cells on Peterson Island.

(i) Intensity of solar radiation

Inactive cells

The inactive cells of Bailey Peninsula (Figure 6.10) have the highest intensity of solar radiation at the four dates in comparison with Ardery and Peterson Islands (Figure 6.11, 6.12). The inactive cells of Peterson Island receive slightly more intensity of solar radiation than the ones of Ardery Island at solstice and on the 31st of January. On the 1st of March and at equinox the inactive cells of the two islands have equal mean values of solar intensity. Results of the Z test indicate that the differences in solar intensity between the inactive cells of the three sites are all significant[288].

Snow petrels

The intensity of solar radiation received by all the groups of snow petrel nests decreases gradually from day 355 to day 80 (Figures 6.10, 6.11, 6.12, 6.13, 6.14). However, some differences can be observed between the different groups. These differences are constant for the four dates investigated. In fact, the order of the six groups according to their value of intensity of solar radiation does not change from day 355 to day 80, as shown in Table 6.7. The northern groups of the three sites have higher values than the Southern groups. These differences are statistically significant as shown by the results of the Z test performed[289]. The northern and southern groups of Bailey Peninsula and Peterson Island have also their respective values of intensity within the same range for the four days

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[288] The results are: $Z = 4.88$; $P < 0.05$ for the inactive cells of Bailey and Ardery Island on day 355; $Z = 10.85$; $P < 0.05$ for the inactive cells of Bailey Peninsula and Peterson Island on day 355; $Z = 3.43$; $P < 0.05$ for the inactive cells of Bailey Peninsula and Ardery Island on day 31; $Z = 8.81$; $P < 0.05$ for the inactive cells of Bailey Pensinsula and Peterson Island on day 31; $Z = 3.29$; $P < 0.05$ for the inactive cells of Bailey Peninsula and Ardery island on day 61; $Z = 8.81$; $P < 0.05$ for the inactive cells of Bailey Peninsula and Peterson Island on day 61; $Z = 2.19$; $P < 0.05$ for the inactive cells of Bailey Peninsula and Ardery Island on day 80; $Z = 8.81$; $P < 0.05$ for the inactive cells of Bailey Peninsula and Peterson Island on day 80.

[289] The results are: $Z = 9.44$; $P < 0.05$ for the northern and southern groups of snow petrel nests on Bailey Peninsula at day 355. At day 31, day 61 and day 80 the results for the same groups are respectively: $Z = 11.2$; $Z = 12.9$; $Z = 11.1$. On Ardery Island, the results for the northern and southern groups of snow petrel nests are: $Z = 25.1$ on day 355; $Z = 27.1$ on day 31; $Z = 31.2$ on day 61; $Z = 26.06$ on day 80. On Peterson Island, the results for the northern and southern groups of snow petrel nests are: $Z = 4.7$ on day 355; $Z = 6.03$ on day 31; $Z = 7.96$ on day 61; $Z = 7.26$ on day 80.

studied. The southern group of Ardery Island has an extremely low value of solar radiation intensity compared to other groups at all times. There is a greater difference between the intensity of the northern group and the Southern group of Bailey Peninsula than on Peterson Island. The differences between the intensity of the northern group and the southern group of Ardery Island are even greater but it is due to the extremely low values of intensity of the Southern group of Ardery Island.

Cape petrels

The intensity of solar radiation received by cape petrels during the four days investigated is within the same range for the northern group of Ardery Island and the cape petrel nests of Peterson Island which all have a north-east aspect, except for one nest with a south-west orientation (Figures 6.13 and 6.14). There is a remarkable difference between the northern and southern groups of Ardery Island; the southern group receiving extremely low values of solar radiation intensity in comparison with the northern group. These differences are statistically significant as shown by the results of the Z test[290].

Table 6.7: Intensity of solar radiation in millions of W/m2 (mean ± standard deviation) for snow petrel and cape petrel nests and inactive cells at the three sites.

	Snow petrels		Cape petrels		Inactive cells
	N.group	S.group	N.group	S.group	
Bailey Peninsula					
day 355	8.2 ± 0.3	6.1 ± 0.8	_	_	7.0 ± 0.5
day 31	6.4 ± 0.4	4.1 ± 0.7	_	_	5.0 ± 0.5
day 61	3.4 ± 0.3	1.5 ± 0.5	_	_	2.1 ± 0.4
day 80	1.5 ± 0.2	0.5 ± 0.3	_	_	0.8 ± 0.2
Ardery island					
day 355	7.7 ± 0.7	3.3 ± 1.1	8.0 ± 0.5	3.5 ± 1.0	6.3 ± 1.8
day 31	5.8 ± 0.7	1.6 ± 0.9	6.1 ± 0.6	1.8 ± 0.9	4.4 ± 1.5
day 61	2.8 ± 0.5	0.2 ± 0.3	3.1 ± 0.4	0.2 ± 0.2	1.9 ± 1.0
day 80	1.2 ± 0.3	0.0 ± 0.1	1.4 ± 0.3	0 ± 0	0.7 ± 0.5
Peterson island					
day 355	7.0 ± 1.0	6.3 ± 0.2	7.2 ± 1.0	_	6.7 ± 1.0
day 31	5.1 ± 0.9	4.3 ±0.1	5.5 ± 0.8	_	4.7 ± 0.9
day 61	2.3 ± 0.6	1.7 ± 0.1	2.7 ± 0.5	_	2.0 ± 0.6
day 80	0.9 ± 0.3	0.5 ± 0.05	1.2 ± 0.3	_	0.7 ± 0.3

[290] The results for the northern and southern groups of cape petrel nests on Ardery Island are: Z = 17.41 on day 355; Z = 18.04 on day 31; Z = 39.99 on day 61; Z = 35.54 on day 80.

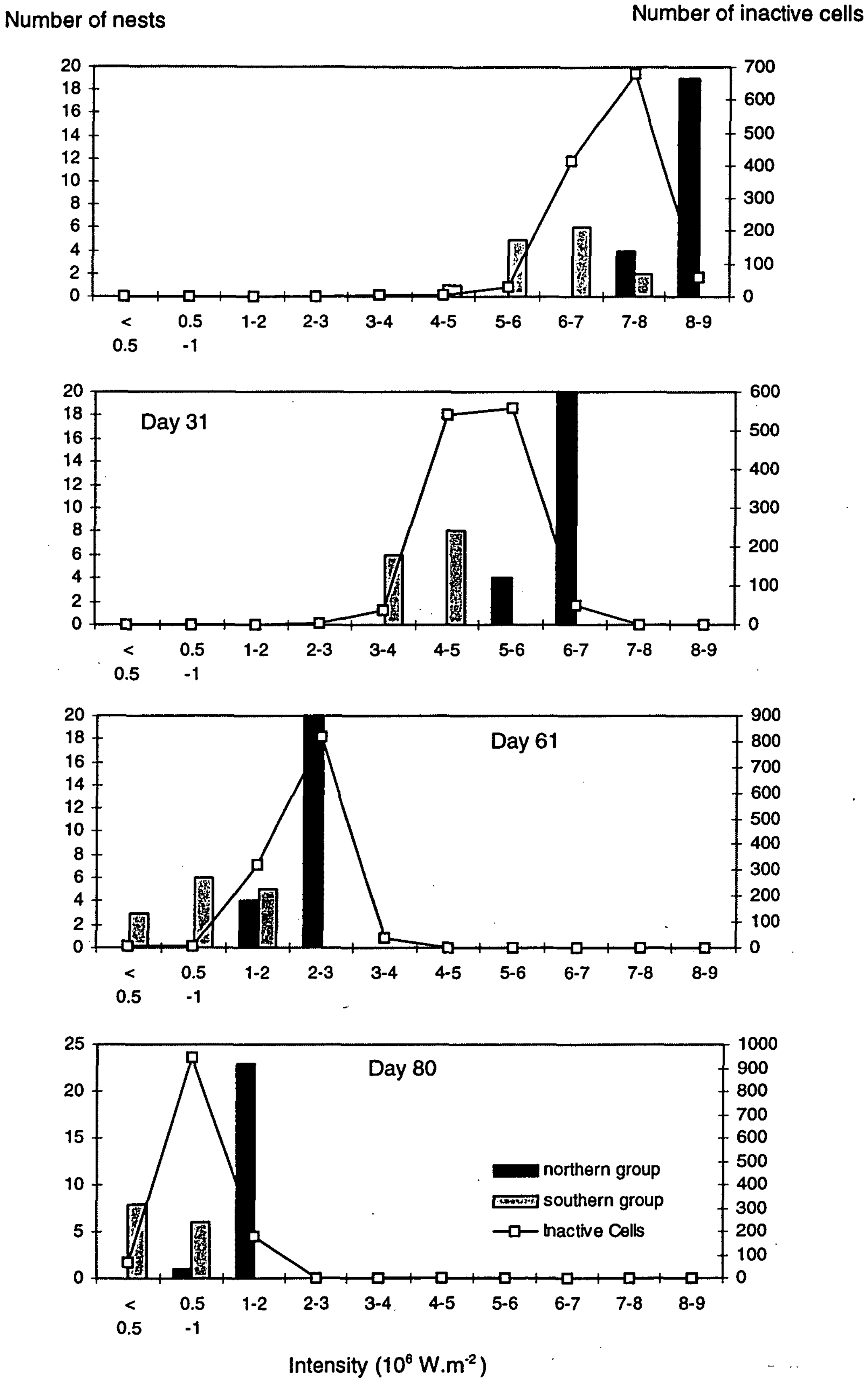

Figure 6.10: Intensity of solar radiation for snow petrel nests and inactive cells on Bailey Peninsula

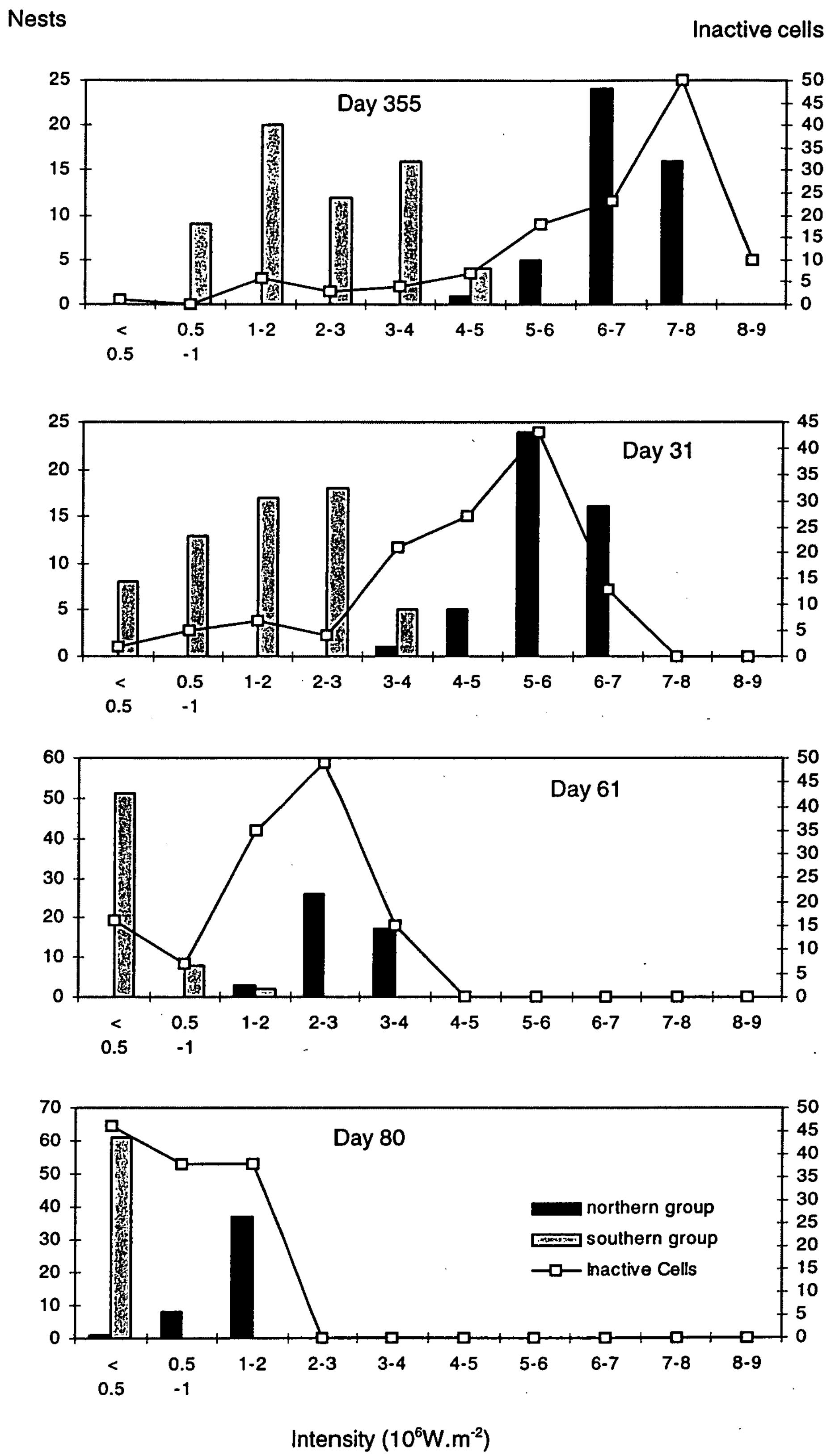

Figure 6.11: Intensity of solar radiation for snow petrel nests and inactive cells on Ardery Island.

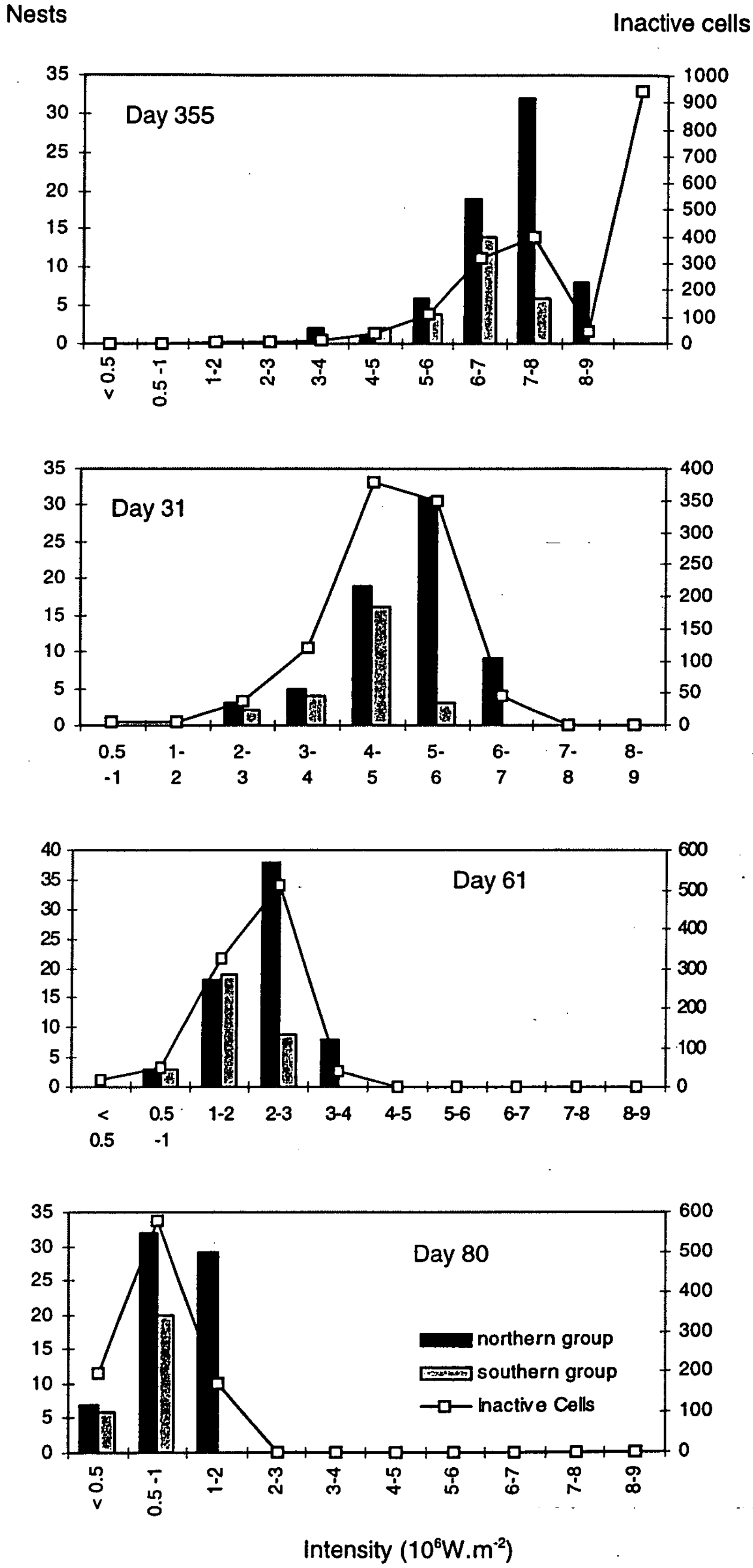

Figure 6.12 : Intensity of solar radiation for snow petrel nests and inactive cells on Peterson Island

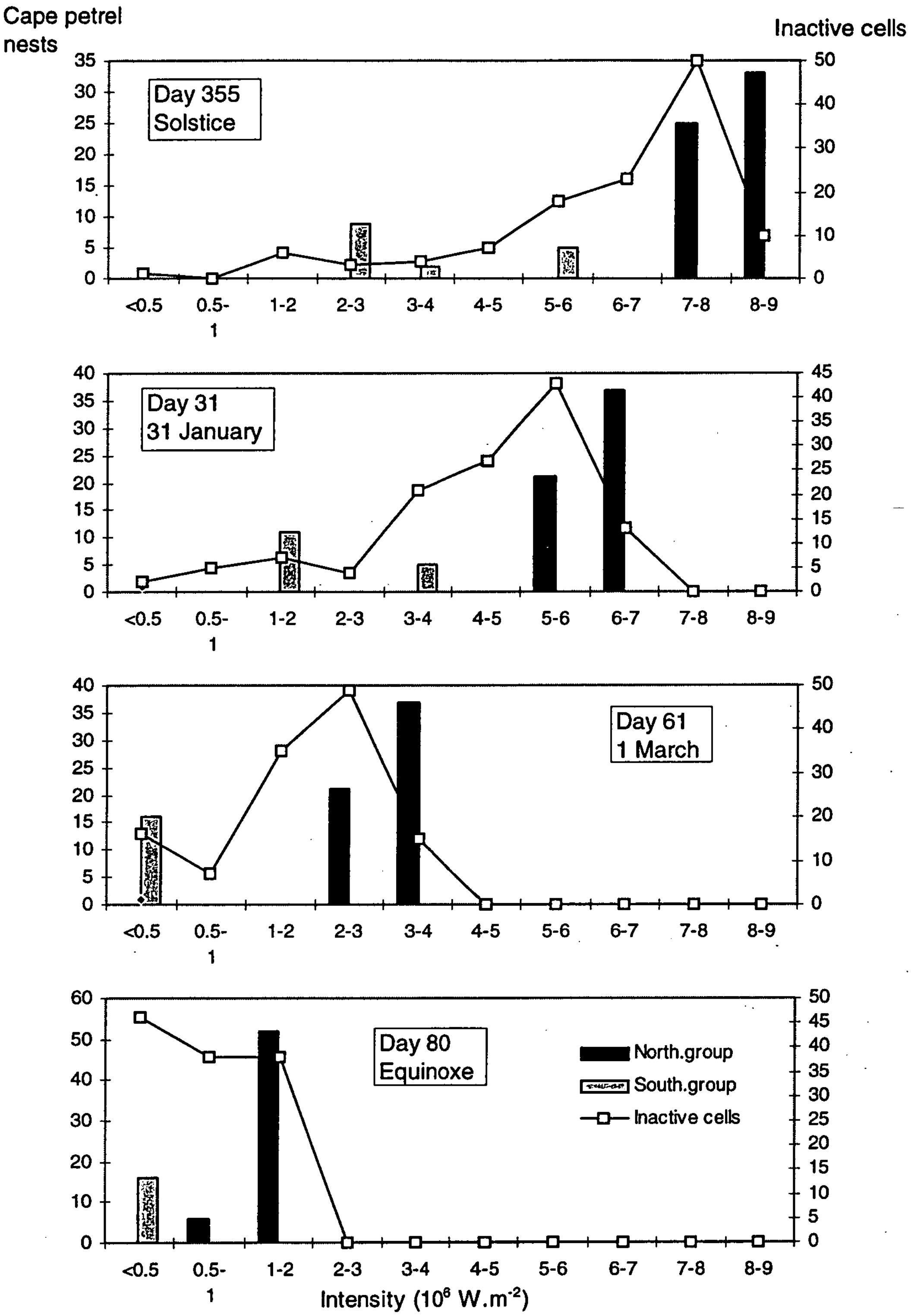

Figure 6.13: Intensity of solar radiation for the cape petrel nests and inactive cells on Ardery Island.

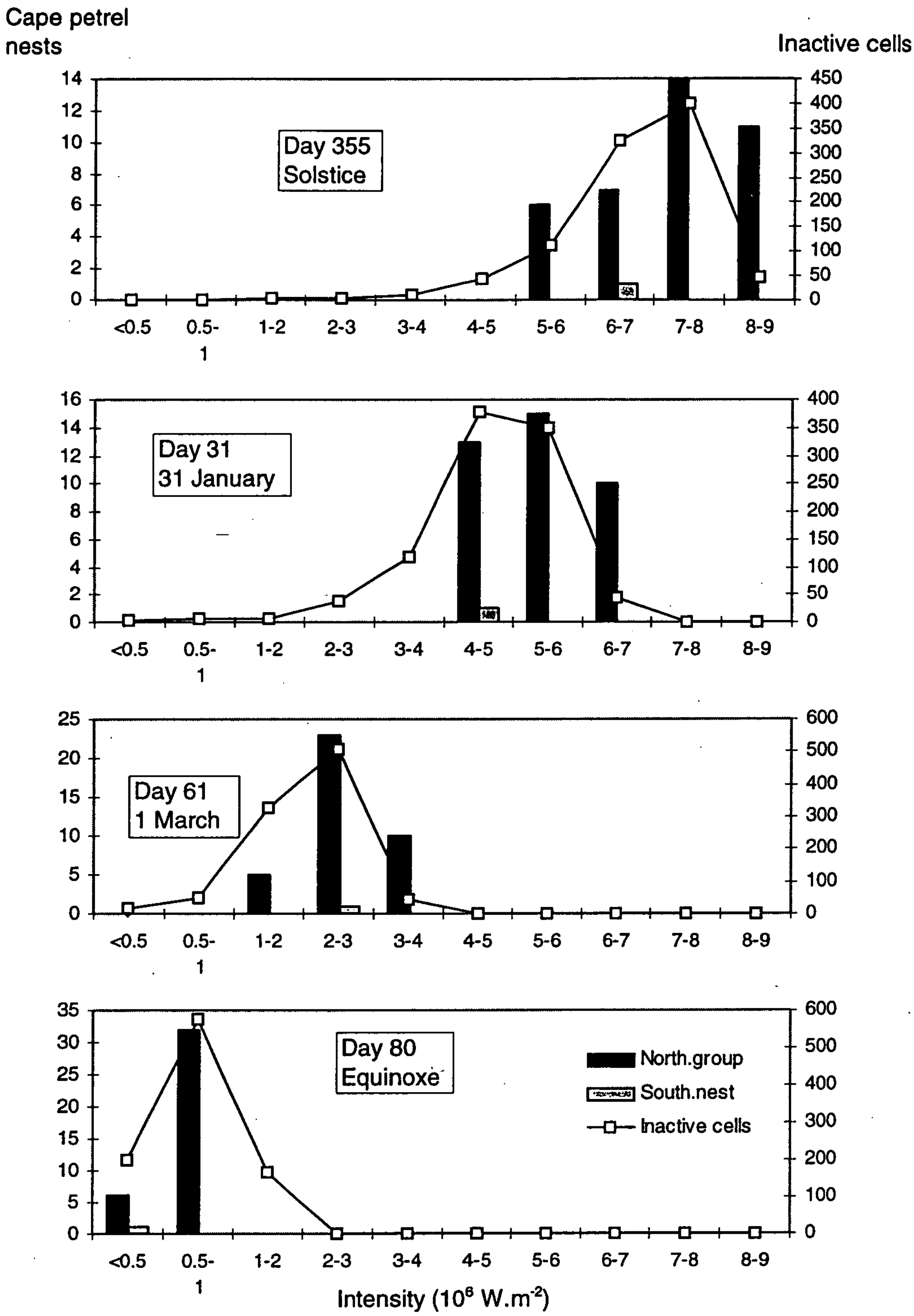

Figure 6.14: Intensity of solar radiation for the cape petrel nests and inactive cells on Peterson Island.

1.2 Discussion

(i) Deviation of nests to the prevailing winds

Of all the parameters analysed, the deviation to the wind appears to be the most significant parameter for both snow petrels and cape petrels in the selection of a nesting site: all the eight groups of snow petrels and the three groups of cape petrels identified in the analysis have an average deviation to the wind in the same range. Such an angle to the wind allows some protection or at least the avoidance of a frontal exposure to the winds. This reflects the extreme meteorological conditions of the Windmill Islands where strong wind events are frequent at all seasons and where wind speeds above 150 km/h are common.

Snow petrels nest in crevices and therefore have a more sheltered nest than the cape petrels which nest in the open. This difference in the degree of shelter given by the nest may explain the differences observed for the deviation to the wind between snow petrel and cape petrel nests (i.e. 75 degrees for the snow petrels and 90 degrees for the cape petrels). An angle perpendicular to the wind would offer more protection to the cape petrels, compensating for the lack of shelter offered by their type of nest.

Snow accumulation resulting from strong winds can also be ameliorated by such a positioning of nests. During blizzards[291], snow tends to accumulate in areas of high turbulence as opposed to areas of laminar flow. The downwind slopes and, to a lesser extent, the upwind slopes are areas of important snow accumulation. On the contrary, areas with an aspect perpendicular to the wind tend to have minimal snow accumulation[292]. This is very important for birds nesting in crevices or in open nests which are in no way snow proof. Another advantage offered by the deviation to the wind is the less turbulent air prevailing at the nest site. This can facilitate access to the nest by providing easier flying conditions in moderate to strong winds.

The fact that on Peterson Island, the snow petrels have an average deviation to

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[291] A blizzard is defined by Monkhouse as "a very strong, bitterly cold wind accompanied by masses of dry powdery snow or ice-crystals, with poor visibility under polar or high- altitude conditions". In: Monkhouse , F.J., op.cit, supra n° 235.

[292] For further details concerning this phenomenon, see: Schwerdtfeger, W., 1984, *Weather and Climate of the Antarctic*, Amsterdam: Elsevier, pp.114-118.

the wind slightly superior to Bailey Peninsula and Ardery Island (ie. respectively 83.3 ±38.0, 71.5 ±28.5 and 66.6 ±23.5 degrees) can be explained by the local variations in the wind and by the differences in the topography of the sites. The strong winds at Casey station are exclusively from the east. On Ardery Island, strong winds are from the south-east in all strong winds events observed during the summer 95-96. On Peterson Island, strong winds are more variable in direction with 50 per cent of the strong wind from the south and almost 30 per cent from the east. As the deviation to the wind at Peterson was calculated from an average between south and east, it is likely that the variable direction of the wind has some effect on the distribution of the nests. The upland areas in the three sites differ. Peterson Island is composed of undulating hills; in contrast, Ardery Island and, to a lesser extent, Reeve Hill on Bailey Peninsula are more uniformly elevated: Reeve Hill is the only hill on Bailey Peninsula which is otherwise a plateau and Ardery Island is surrounded by high cliffs. On Peterson Island, because of the probable wind shadow effect of some hills, the wind tends to vary in direction and in intensity within the island. The snow petrels may have to adapt to such local variations in wind direction and intensity. It was not possible to analyse these local wind variations within the scope of this thesis. However, it is likely that local variations of the wind may have an effect on the distribution of the nests within the island.

(ii) Intensity of solar radiation

If the wind were the only significant variable, the distribution would be symmetrical between the northern and southern groups on each site. This is not the case since on Bailey Peninsula and Peterson Island respectively 63 per cent and 72 per cent of the nests are in the northern group. Another significant parameter between the northern groups of the three sites and the southern groups of Bailey Peninsula and Peterson Island is the intensity of solar radiation at all times. The southern group of snow petrel nests on Ardery Island have exceptional values which will be addressed later in the discussion. Most snow petrels are in the northern group nest on sites with exceptionally high intensity values of solar radiation from the end of September to the end of March. There are several possible effects of high solar intensity values, some indirect ones on the nest sites and some direct ones on the birds.

The first indirect advantage presented by these areas is that the energy received from the sun melts the snow on the ground very early in the season, clearing the site for the breeding period. The cape petrels and snow petrels arrive at their nests respectively in mid-October and late October onwards. As Beck notes with respect to snow petrels, "they are capable of clearing small amounts of loose snow, but are unable to deal with ice and hard-packed snow blocking sheltered sites"[293]. This remark suggests that the requirement of nests to be free of snow very early in the spring is an important one for the birds.

Another indirect advantage is that the high intensity of solar radiation will help melt any residual snow very quickly. It was noted above that snow petrels avoid areas of snow drift occurring during blizzards. However, after a blizzard, there is a residual amount of snow on the ground, usually 1 or 2 cm, which cannot be avoided. As blizzards can be frequent, the risk of residual snow building up on the nest is real. However, in the areas of high intensity, this residual snow melts within a few hours. The consequence of local snow accumulation on the nest is that if a large quantity of snow is involved, it may inundate the nest when it melts afterwards. Kamenev observed during the summers 1961-62 and 1965-66 that inundation was the main cause for the loss of eggs affecting the snow petrel colony of Haswell Island[294]. He noted that a substantial number of eggs were frozen when nests got snow drift and subsequent ly inundated by the melt water and frozen when the temperature fell below 0°C. The risk of inundation is also minimized for the northern groups of snow petrels since the steeper slope ensures efficient drainage.

The intensity of solar radiation appears to be an important factor for the cape petrels as shown by the differences in the distribution of cape petrels and snow petrels on Peterson Island and Ardery Island. Cape petrels exclusively nest in the areas of Peterson Island with high intensities of solar radiation. On Ardery Island, the fact that there is a larger proportion of cape petrel nesting on the northern side (78%) seems to indicate that cape petrels are more sensitive to the direct effect of solar radiation than are snow petrels. The direct effect can be identified as the calorific input for the birds, and particularly for the chicks after emancipation from total reliance on parental heat. As Kamenev observes for the cape petrel chicks, the initial signs of a stable body temperature were first detected in the juveniles at the age of 11 days. They can then survive for a short time without being brooded, especially in fair weather. Development of the temperature regulation mechanism proceeds rapidly and after 18-22 days the

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293 Beck, P.P., 1970, Ecology and Population Dynamics of Antarctic Seabirds, In: (Holdgate, M.V., ed.) *Antarctic Ecology*, London: Academic Press.

294 Kamenev, V.M., op.cit, supra n° 246, p.229.

parents cease to brood the young[295]. Referring to the breeding cycle of the cape petrel described by Kamenev[296], chicks achieve thermoregulation by the end of January. Since cape petrels nest in the open, they are more exposed to the harsh conditions of the Antarctic though they are also more prone to benefit from the heat received from the sun.

Unlike the cape petrel, the intensity of solar radiation does not appear to have a direct calorific effect on the snow petrel chicks after the incubation period (contra our hypothesis above). This is not very surprising however, since the snow petrels nest in crevices and are not directly exposed to the sun.

(iii) Duration of solar radiation

Duration, as opposed to the intensity of solar radiation, does not appear to be a significant variable for explaining habitat selection for the snow petrels and cape petrels since the average duration of solar radiation for the Northern groups of both species is much lower than for the inactive cells. This can be explained by the fact that the aspect and slope of the northern groups of both species enable them to receive very high values of solar intensity.

For the southern groups, the duration values of solar radiation are higher than for the northern groups of both species and their respective inactive cells. This can be explained that the fact that on both Bailey Peninsula and Peterson Island, southern groups have a smaller slope than the northern groups which enable them to receive more duration of solar radiation.

(iv) Elevation

Ardery Island contains the largest concentration of seabirds within the Windmill Islands. The number of snow petrel nests on Ardery Island was estimated at 1000 nests by van Franeker *et al.* [297] (compared to 38 and 94 respectively on Bailey Peninsula and Peterson Island). Secondly, the distribution of nests within the northern and the southern group is roughly equal with 450 nests in the northern colonies and 550 nests in the southern colonies. While Bailey Peninsula and Peterson Island contain fewer numbers of snow petrel and cape petrel nests in comparison, these two sites share common habitats requirements with Ardery Island, such as the deviation of nests to the

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[295] Kamenev, V.M.., op.cit, supra n° 246, p.228.

[296] Kamenev, V.M., op.cit, supra n° 246, p.229.

[297] van Franeker, J.A., Bell, P.J., Montague, T.L., op.cit, supra n° 237.

prevailing winds which are discussed in the following section. However, the specific conditions of Ardery Island need to be discussed in order to explain the abundance of the bird population. The topography of Ardery Island is exceptional within the Windmill Islands; this site is very elevated (110m) and surrounded by impressive cliffs on all sides. Due to the topographic characteristics of Ardery Island, wind and snow conditions vary, influencing the snow petrel nest distribution.

Schwerdtfeger[298] detailed the phenomenon of wind-driven snow: the snow particles are carried by the wind in the lowest layer of air above the surface. As Schwerdtfeger notes: "Drifting snow can be initiated and maintained" by moderate winds, "becoming more dense and increasing its vertical extent as wind and its turbulence [in the lowest layer] intensify. (...) The vertical extent of the snow particle-filled atmospheric layer may be between 2m and, under extreme conditions, a couple of hundred meters"[299]. The quantity of snow driven by the wind decreases with the elevation above ground level[300]. Because snow petrels and cape petrels nest on the ground they are very likely to be affected by blowing snow even in moderate wind conditions. Furthermore, the lowest layer of wind is strongly influenced by the topography. When the topography is smooth, the lowest layer of wind follows the topography and blowing snow accumulates preferentially on the leeward side of locations. This is the case for the whole of the plateau of Bailey Peninsula with the exception of Reeve Hill. When the topography is more abrupt, the lowest layer of the wind varies in direction and force. For example, on Peterson Island, the lowest layer of wind is canalised by the hills and flows preferentially in the wind corridor between the hills. The peaks are less affected by blowing snow than the valleys. However, the hills are not high or abrupt enough to be totally devoid of blowing snow. On Bailey Peninsula, Reeve Hill is not very abrupt. However, the fact that this site has the same orientation as the strongest winds decreases the amount of blowing snow in moderate wind conditions in comparison to the rest of Bailey Peninsula. Finally, Ardery Island, with its high elevation, its high cliffs on all sides and its general orientation to the strongest winds, is almost totally devoid of blowing snow in its higher part. This is confirmed by

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298 Schwerdtfeger, W., op.cit, supra n° 292, p.114-118.

299 Schwerdtfeger, W., op.cit, supra n° 292, p.114.

300 For example, Schwerdtfeger cites a study which consisted of measuring the density of blowing snow for different elevations above ground level. For a 12m/sec wind (43 km/h), 0.4 gram.m^{-3} of snow at 1meter above ground level and only 0.07 gram.m^{-3} at 10m above ground level were measured. See Schwerdtfeger, W., op.cit, supra n° 292, p.116.

observations at the camp site of Ardery Island during the summer campaign (December 95-April 96). During strong wind events, when blizzard conditions prevailed on Bailey Peninsula and Peterson Island, no snow blew on the Ardery Island camp which was located at about 50 metres above sea level. The avoidance of blowing snow is a factor which may explain the fact that snow petrels and cape petrels select sites with a noticeably higher elevation than the inactive cells at all sites. The fact that Ardery Island is devoid of blowing snow explains the exceptionally high concentration of nesting birds compared to lower sites such as Bailey Peninsula or Peterson Island. There is no difference in the distribution of snow petrel nests between the northern and the southern colonies, since both colonies are located in elevated areas receiving limited amount of blowing snow. Consequently, the intensity of solar radiation is not a predominant factor for the snow petrels on Ardery Island: its melting effect on the snow is not as important as on Bailey Peninsula, and to a lesser extent, Peterson Island, where blowing snow is common.

(v) Differences between northern and southern groups on Bailey Peninsula and Peterson Island

The situation of the southern groups of Bailey Peninsula and Peterson Island is quite different from the northern groups, with the exception of the intensity of solar radiation. In comparison to parameters such as slope and duration, the southern groups have a value of intensity which is similar, although smaller, to those of the northern groups. The difference is due to their southern aspect. However, because the Southern groups of snow petrels have a smaller slope than the northern groups on both Bailey Peninsula and Peterson Island, the southern groups of the two locations have higher durations of solar radiation at solstice. The combination of small slopes and, consequently, high durations of solar radiation enable the snow petrels to compensate for the low intensity values of solar radiation they receive because of their southern aspect.

However, the duration values decrease rapidly as the sun has a more northern course during the summer period and the values of intensity decrease proportionally after solstice. The variables such as slope and intensity of solar radiation can be discussed in terms of advantages for the southern groups in the same way as they were discussed for the northern groups. However, it is clear that the smaller intensity of solar radiation at all times is such that the nests are likely to be free of the winter snow much later in the season. Furthermore, the residual snow will persist longer on the nest after the blizzards, or even build up later in the season. Finally, the smaller slope will increase the risk of inundation. All together, the situation of the southern groups of Bailey Peninsula and Peterson Island does not seem as favourable as for the northern groups of the three sites. This may explain the fact that more than 60 per cent of the snow petrels are in the northern group of Bailey Peninsula and Peterson Island.

(vi) Slope and elevation

Slope contributes to an efficient drainage of the snow melt and therefore minimizes the risk of nest inundation. Along with aspect, slope is also a contributing factor to the duration and intensity of solar radiation nests receive, as detailed above. The importance of elevation has been discussed before with respect to Ardery island. However, the variability of elevation values for the nests of both species suggests that they can adapt to the topographic conditions of each site by selecting elevated areas within locations.

2. Multivariate Analysis

As Kvamme notes, a univariate analysis is insufficient for modelling habitat suitability because it cannot answer the question of overall environmental differences between sites occupied by nests (or active cells) and unoccupied sites (or inactive cells) when all variables are considered jointly[301]. Regression analysis is used for predicting the values of a dependent or response variable based upon the values of at least one explanatory or independent variable identified in the univariate analysis[302]. Regression encapsulates the form of the relationship between the dependent and independent variables in mathematical terms, as an equation. A logistic regression was applied for predicting the presence/absence of nests and a multiple stepwise regression was applied to predict the density of nests.

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[301] Kvamme, L., 1985, Determining empirical relationships between the natural environment and prehistoric site conditions: a hunter gatherer example, In: (Carr, C., ed.) *For Concordance in Archeological Analysis*, Kansas City, Kansas: Westport publishers, pp. 208-238.

[302] Berenson, M.L., Levine, D.M., 1992, Basic Business Statistics: Concepts and Applications, Englewood Cliffs, N.J: Prentice Hall, p. 605.

2.1 Logistic regression

A distinction was made between Ardery Island, for which only two independent variables appeared significant in the univariate analysis (ie. slope and deviation from the prevailing wind), and Bailey Peninsula and Peterson Island, for which an additional variable, the intensity of solar radiation, explained the distribution of the northern and southern groups of snow petrel nests.

A logistic regression model was conducted for predicting the occurrence of snow petrel nests on Ardery Island. The model was obtained by using the regression function in the GRID module of ARC/INFO with a grid of presence and absence of nests (dependent variable), and two independent environmental variables: slope and deviation to the prevailing wind.

As shown in Figure 6.4, snow petrel nests do not have a linear distribution with respect to slope. The logistic regression therefore had to be transformed in order to coincide with the ecological conditions of the snow petrel nests (the majority of nests corresponding to an interval of minimum and maximum values of slope)[303]. In other words, the relationships between the variables is simplified to one that is linear in its transformation[304]. The transformation added the square of the slope as an additional independent variable to the equation. The following coefficients were obtained from the regression function:

Table 6.8: Logistic regression for predicting the occurrence of snow petrel nests on Ardery Island.

Grids	Coefficients	Intercept
deviation to prevailing wind	-0.010	
slope	0.735	-9.700
$slope^2$	-0.012	
RMS	0.364	
Chi-Square	25.464	

303 If untransformed, the logistic regression predicts that cells with the highest probability of nest occurrence will be found in areas of extreme values of slope which is in disagreement with the results of the univariate analysis and observations made in the field.

304 For details of regression models using transformations see: Berenson, M.L., Levine, D.M., op.cit, supra n° 302, p. 705.

These coefficients were inserted in the following equation in order to obtain a grid of probability of occurrence/absence (of nests) resulting in surface prediction, wherein "p" is the probability of snow petrel nest occurrence at a given cell:

$$p = 1/\ (1+ \exp\ (\ -\ (-9.700 + (-0.010 \times \text{deviation}) + (0.735 \times \text{slope}) + (-0.012 \times \text{slope}^2)\ )\ )$$

The surface prediction derived from the transformed logistic regression coincides with the colonies identified by Franeker *et al.* [305]. It appears that this predictive method reflects the ecological conditions of snow petrel nests on Ardery Island based on the two independent variables inputted.

The logistic regression was then applied to Bailey Peninsula and Peterson Island for which the influence of solar radiation was identified as a discriminative factor in the distribution of the northern and southern groups.

The logistic regression was computed for Bailey Peninsula using the northern group of snow petrel nests as these coincide with most suitable conditions and with the majority of nests. Considering the different environmental conditions identified in the univariate analysis for the northern and southern groups of snow petrels of Bailey Peninsula and Peterson Island, it is not possible to devise a logistic regression model that would include both groups. Indeed, the output surface predictions would provide a grid of highest probability of nest occurrence for areas corresponding to the average of the environmental conditions of the two distinctive groups. Such areas would not include the most suitable habitat conditions since both groups have different environmental conditions in terms of slope and solar intensity, as shown in the univariate analysis.

For both Peterson Island and Bailey Peninsula the number of inactive cells is far greater than active cells. Previous logistic regression used for habitat modelling, such as the Mt Graham Red Squirrel application of Pereira and Itami[306], used a ratio of non-sites to sites larger than one (259 inactive cells and 212 active cells)[307]. In this case study, the number of inactive cells was therefore reduced in

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[305] van Franeker *et al.*, op.cit, supra n° 237.

[306] Pereira, J.M.C., Itami, R.M., op.cit, supra n° 277.

[307] Pereira, J.M.C., Itami, R.M., op.cit, supra n° 277, p. 1480.

order to obtain a ratio between inactive and active cells closer to one. Inactive cells were selected within a 200 metres by 200 metres grid restricted to snow free areas for Bailey Peninsula and a 150 metres by 150 metres grid restricted to snow free areas for Peterson Island. The coefficients obtained from the regression function are listed in Table 6.9:

Table 6.9: Logistic regression based on the environmental variables predicting the occurrence of snow petrel nests on Bailey Peninsula.

Grids	Coefficients	Intercept
deviation to prevailing wind	-0.030	
slope	0.139	
slope^2	0.002	-12.374
solar intensity (day 31)	0.183	
RMS	0.284	
Chi-Square	5.573	

These coefficients were inserted in the following equation in order to obtain a grid of probability of occurrence/absence (of nests) resulting in surface prediction:

$p = 1/\ (1 + \exp\ (\ -\ (\ -12.374\ -\ (0.030 \times \text{deviation}) + (0.139 \times \text{slope}) + (0.002 \times \text{slope}^2) + (0.183 \times \text{solar intensity})\ )\ )$

The surface prediction obtained coincides with most suitable conditions for snow petrel nests.

The applicability of the logistic regression was tested on Peterson Island which has a similar elevation to Bailey Peninsula. The equation calculated for the northern group of snow petrel nests and the inactive cells of Bailey Peninsula was therefore applied to Peterson Island. However, the average probability of nest occurrence for the active cells (i.e. for which nests are already recorded) was extremely low (p = 0. 284) in comparison with Bailey Peninsula and Ardery Island, as summarised in Table 6.11.

Consequently, a logistic regression was computed using the northern group of snow petrel nests and the inactive cells of Peterson Island. The regression function provided the following coefficients:

Table 6.10: Logistic regression based on the environmental variables predicting the occurrence of snow petrel nests on Peterson Island.

Grids	Coefficients	Intercept
deviation to prevailing wind	-0.015	
slope	0.167	
$slope^2$	-0.003	-6.594
solar intensity (day 31)	0.114	
RMS	0.424	
Chi-Square	28.053	

These coefficients were inserted in the logistic regression equation used for computing a grid of surface prediction for Peterson Island. The results improved, since the average probability of nest occurrence within active cells (i.e for which nests are already recorded) was higher than in the surface prediction derived from Bailey Peninsula ($p = 0.467$). However, a comparison of the probabilities of nest occurrence within the inactive and active cells at the three sites reveals a variability in the results to the detriment of Peterson Island, as summarised in Table 6.11.

Table 6.11: Probabilities of nest occurrence derived from the logistic regression at the three sites.

Sites	Average probability ± standard deviation
Bailey Peninsula	
active cells (Northern group)	0.72 ± 0.402
inactice cells	0.048 ± 0.147
difference	0.682
Peterson Island	
using Bailey's regression	
active cells (Northern group)	0.284 ± 0.312
inactive cells	0.145 ± 0.282
difference	0.159
Peterson Island	
using Peterson's regression	
active cells (Northern group)	0.467 ± 0.198
inactive cells	0.273 ± 0.17
difference	0.294
Ardery Island	
all active cells	0.548 ± 0.157
inactive cells	0.182 ± 0.236
difference	0.366

The probabilities of the surface predictions obtained for the three sites show the limitations of the logistic regression model. The relatively low probabilities obtained for the active cells can be explained by the fact that only northern groups of snow petrels were considered in the model as these fulfill the most suitable habitat conditions.

The differences between the average probability of active and inactive cells is minimal on Peterson Island whichever regression is used. The lack of discrimination between snow petrel nests (active cells) and the background (inactive cells) can be explained on Peterson Island by the wider distribution of snow petrel nests in terms of aspect, deviation to the prevailing wind and the intensity of solar radiation. The logistic regression shows limitations in such a case, with relatively low probabilities of nest occurrence for Peterson Island in comparison with Ardery Island and Bailey Peninsula.

This limitation leads to the rejection of the logistic regression model for determining areas of habitat suitability. A model based on the selection of intervals for the environmental variables measured on snow petrel and cape petrel nests was then tested and chosen as the most appropriate habitat suitability model. This model is discussed in section 3 of this chapter.

2.2 Multiple stepwise regression analysis

Hair *et al.* define multiple regression analysis as a "statistical technique that can be used to analyse the relationship between a single dependent (criterion) variable and several independent (predictor) variables. The objective of multiple regression analysis is to use the independent variables whose values are known to predict the single dependent value selected by the researcher"[308]. The multiple regression seeks to obtain an equation that predicts the level of the dependent variable. Each predictor is weighted, the weights denoting their relative contribution to the overall prediction. As Hair *et al.* note, the regression equation is a linear combination of the independent variables that best predicts the dependent variable[309]. In this case study, multiple regression analysis is used in order to predict the density of nests, the dependent variable. The stepwise regression procedure is described by Afifi and Clark as follows: "the standard stepwise regression programs do forward selection, which consists of

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[308] Hair, J.F.; Anderson, R.F.; Tatham, R.L.; Black, W.C., 1995, *Multivariate Data Analysis with Readings*, Englewood Cliffs, N.J: Prentice Hall, p.85.

[309] Hair *et al.*, op.cit, supra n° 308, p.86.

adding a variable one at a time to the predictive equation, with the option of removing some variables already selected"[310].

Using the SYSTAT statistical software program[311], a stepwise regression model was used to derive a model for predicting nest density (dependent variable) using the following measured environmental variables (independent variables): slope, aspect, elevation, deviation from the prevailing wind, and solar radiation intensity on day 355. The regression model was significant for the snow petrel nests of Bailey Peninsula (ANOVA, $F_{4, 178} = 44.2$, $P < 0.001$) and the regression model accounted for half of the variation in nest density (squared multiple R = 0.499).

Table 6.12: Stepwise Multiple Regression model for snow petrel nest density on Bailey Peninsula

Independent Variables	Coefficient	Std Error	Std Coefficient	Tolerance	T	P (2 Tail)
constant	0.742	0.371	0	_	1.999	0.047
slope	0.039	0.003	0.687	0.737	11.111	0
deviation from 90°	-0.002	0.001	-0.148	0.973	-2.745	0.007
elevation	0.015	0.003	0.275	0.993	5.172	0
solar intensity (day 355)	-0.015	0.005	0.176	0.75	-2.877	0.005
Summary						
Multiple R	0.706	_	_	_	_	_
Squared Multiple R	0.499	_	_	_	_	_
Adj. Squared Multiple R	0.487	_	_	_	_	_
Standard Error Estimate	0.488	_	_	_	_	_
Analysis of Variance	**Sum of Squares**	**DF**	**Mean Square**	**F-Ratio**	**P**	
regression	42.103	4	10.526	44.257	<0.001	
residual	42.334	178	0.238			

Using the statistical program SigmaStat, a non-parametric Kruskal-Wallis ANOVA on Ranks was performed in order to identify significant differences between nest density and inactive cells on Bailey Peninsula for the deviation to the prevailing wind. The differences in the median values among the density groups are greater than would be expected by chance with a statistically significant difference ($P = 0.00466$). There is a significant difference in the deviation to the prevailing wind between zero nests (inactive cells) and single nest sites (K.W. ANOVA $H = 13.0$, $P < 0.01$), but no difference was detected in median values between other nest densities. This could reflect the low sample

[310] Afifi, A.A.; Clark, V.; 1996, *Computer-Aided Multivariate Analysis*, London: Chapman & Hall, p.179.

[311] SYSTAT, Inc. *SYSTAT for Windows, version 5.*

size for nest densities greater than one.

For the snow petrel nests of Peterson Island, the regression model only accounted for a very small proportion (squared multiple R = 0.028) of the variation in nest numbers. However, the model was significant for Peterson Island (ANOVA, $F_{4, 1492} = 10.731$, $P < 0.001$).

Table 6.13: Stepwise Multiple Regression model for snow petrel nest density on Peterson Island.

Independent Variables	Coefficient	Std Error	Std Coefficient	Tolerance	T	P (2 Tail)
constant	-0.211	0.068	0.000		-3.127	0.002
slope	0.003	0.001	0.12	0.732	4.023	0
deviation from 150°	-0.001	0	-0.091	0.675	-2.940	0.003
elevation	0.002	0	0.099	0.922	3.706	0
solar intensity (day 355)	0.004	0.001	0.12	0.557	3.524	0
Summary						
Multiple R	0.167	_	_	_	_	_
Squared Multiple R	0.028	_	_	_	_	_
Adj. Squared Multiple R	0.025	_	_	_	_	_
Standard Error Estimate	0.291	_	_	_	_	_
Analysis of Variance	**Sum of Squar**	**DF**	**Mean Square**	**F-Ratio**	**P**	
regression	3.638	4	0.91	10.731	<0.001	
residual	126.459	1492	0.085			

However, attempts to clarify the influence of the environmental variables on nest density are confounded by low numbers of replicates for nest densities greater than one or two. As well, the inactive cells (zero nests) were overwhelmingly represented in the data set.

2.3 Ordination

Gauch defines the purposes of ordination as follows: "ordination serves to summarize community data by producing a low-dimensional ordination space[312] (of typically one to three dimensions) in which species and samples which are similar are close together and dissimilar entities far apart"[313]. In this case study, ordination techniques were performed using the SSH module of

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312 an ordination space is a space on to which the sites are projected whereby the distance between the sites is related to their similarity or dissimilarity.

313 Gauch, H.G., 1982, *Multivariate Analysis in Community Ecology*, Cambridge: Cambridge University Press, p.118.

PATN, a software package written by Belbin[314] for the manipulation, analysis and display of patterns in data. The raw data was transformed as rank data with average rank on ties. As Gauch notes, pattern analyses begin with no specific hypotheses; their function is to elicit, from a quantity of often complex data, some internal structure from which hypotheses can be generated[315].

PATN provides the correlation[316] value for each variable to the ordination (using the PCC module in PATN) and calculates the probability that the correlation is in fact due to the ordination and not to random chance (using a Monte Carlo technique, MCAO module in PATN). Based on such probability, the variables which appear to be significant are plotted in the same ordination space. For example, the amount of solar radiation had a correlation value less than 50 per cent which suggested that it was not worth plotting. The SSH module first fixes the position of each cell into a multidimensional space determined by the particular values of the variables measured for that cell; each measured variable can be plotted as a vector in the ordination space. PATN therefore provides a summary of the relationships of the different variables. The SSH module then performs multidimensional scaling which means that the multidimensional relationship between the nests is projected into fewer dimensions (usually two) thus facilitating the visual representation of the data. This simplification into two dimensions is done in a way that preserves the relationships between the cells (i.e. the distance between cells which is reflected in two dimensions retains most of the actual distance in multidimensional space). PATN also provides a measure of the goodness of fit (or stress) of the two dimensional diagram to the multidimensional one. In other words, PATN provides a measure of how well the two dimensional solution reflects the true multidimensional arrangement of the sites. If stress is above 0.2, then the two dimensional solution is not a good summary of the data. The results of the ordination performed with PATN confirm to a large extent the findings of the univariate analysis.

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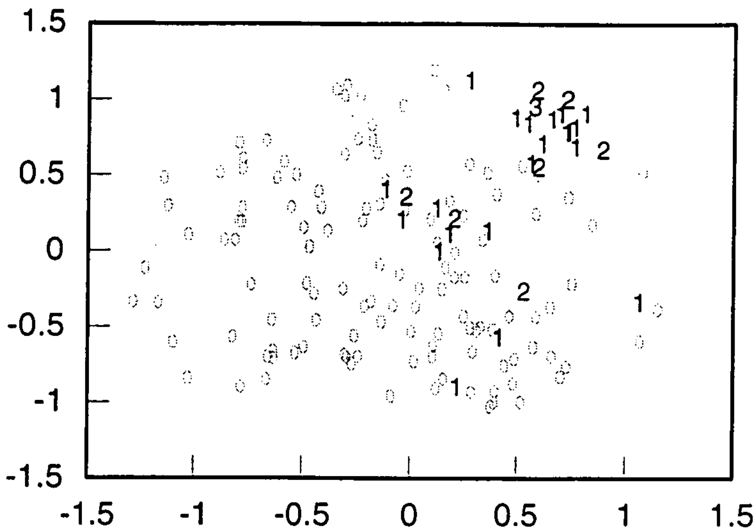
314 Belbin, L., 1995, *PATN Pattern Analysis Package: Users Guide and Technical Reference*, CSIRO Australia, Division of Wildlife and Ecology.

315 Gauch, H.G., op.cit, supra n° 313, p.12.

316 Two variables are said to be correlated if there is an association between them. The strength and direction of association between independent data pairs may be informally assessed by a scatterplot of the values of Yj against Xj.



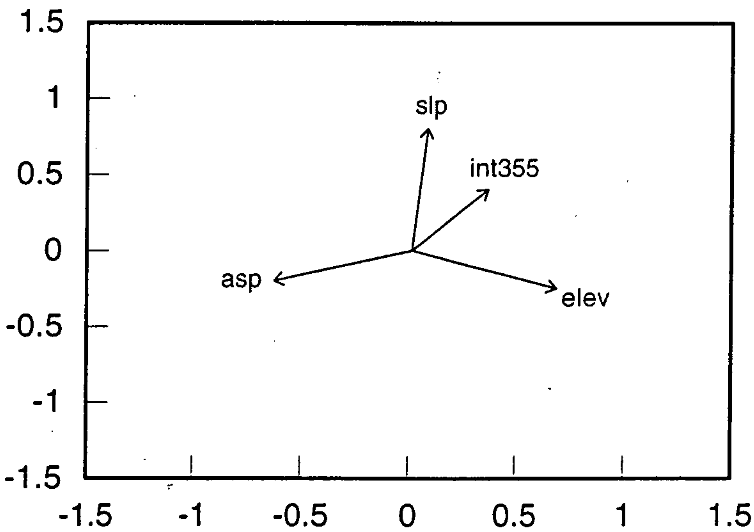


Figure 6.15 upper: Ordination of snow petrel nests (1-3) and inactive cells (0) on Bailey Peninsula; lower, significant variables fitted as vectors in the same ordination space.

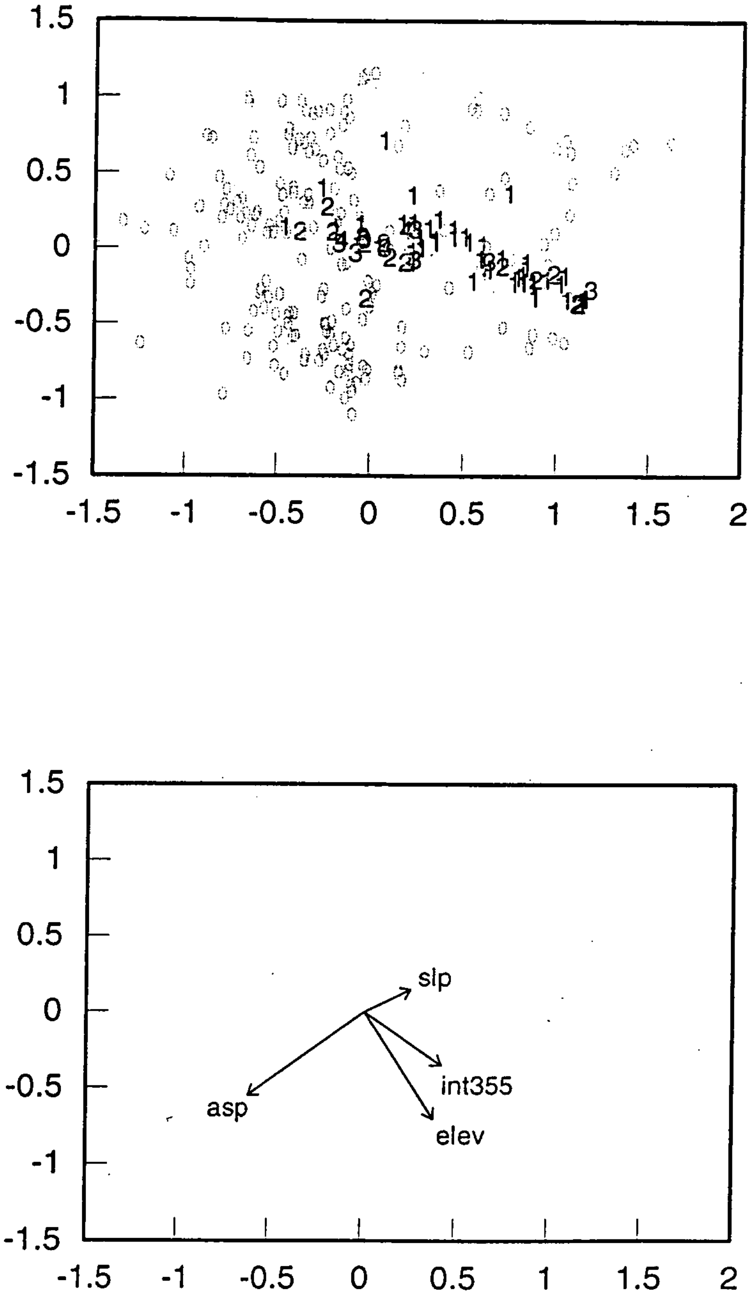
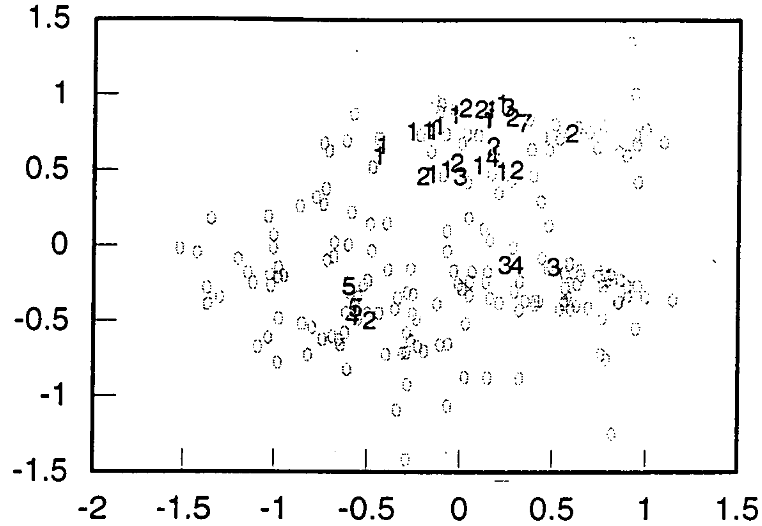


Figure 6.16 upper: Ordination of snow petrel nests (1-4) and inactive cells (0) on Ardery Island; lower, significant variables fitted as vectors in the same ordination space.



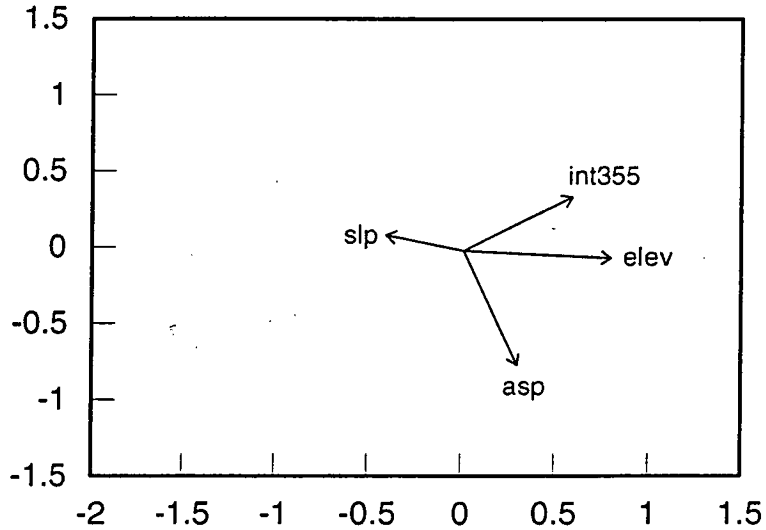
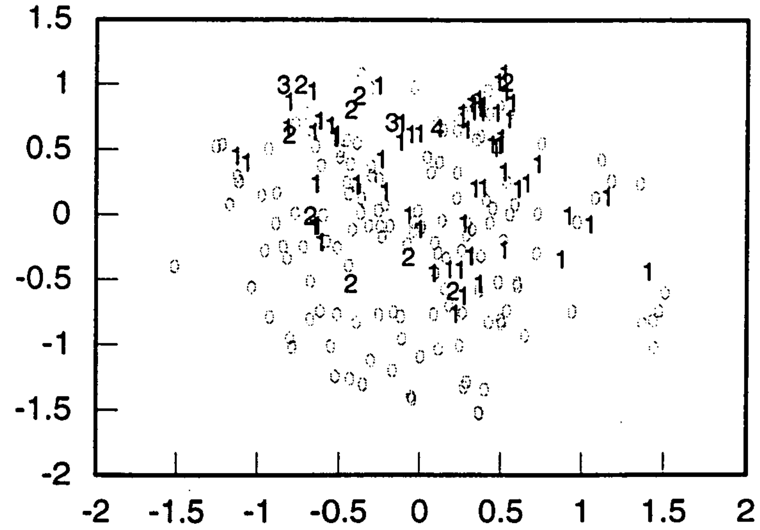


Figure 6.17 upper: Ordination of cape petrel nests (1-5) and inactive cells (0) on Ardery Island; lower, significant variables fitted as vectors in the same ordination space.



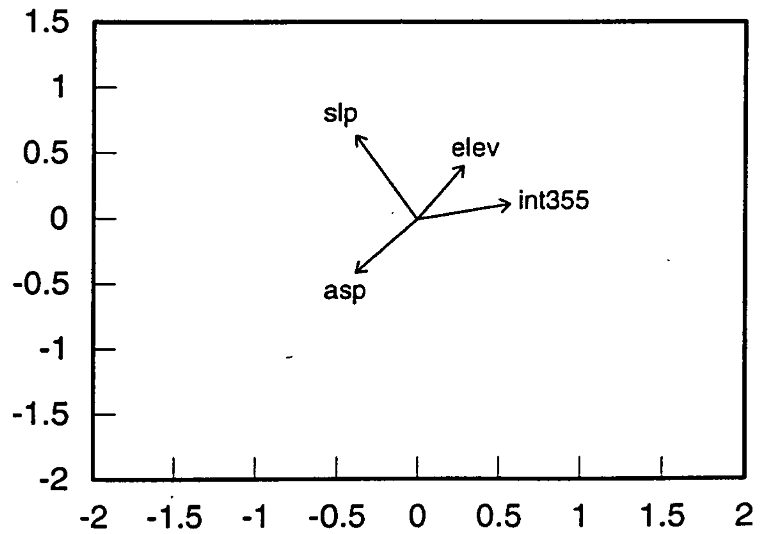


Figure 6.18 upper: Ordination of snow petrel nests (1-4) and inactive cells (0) on Peterson Island; lower, significant variables fitted as vectors in the same ordination space.

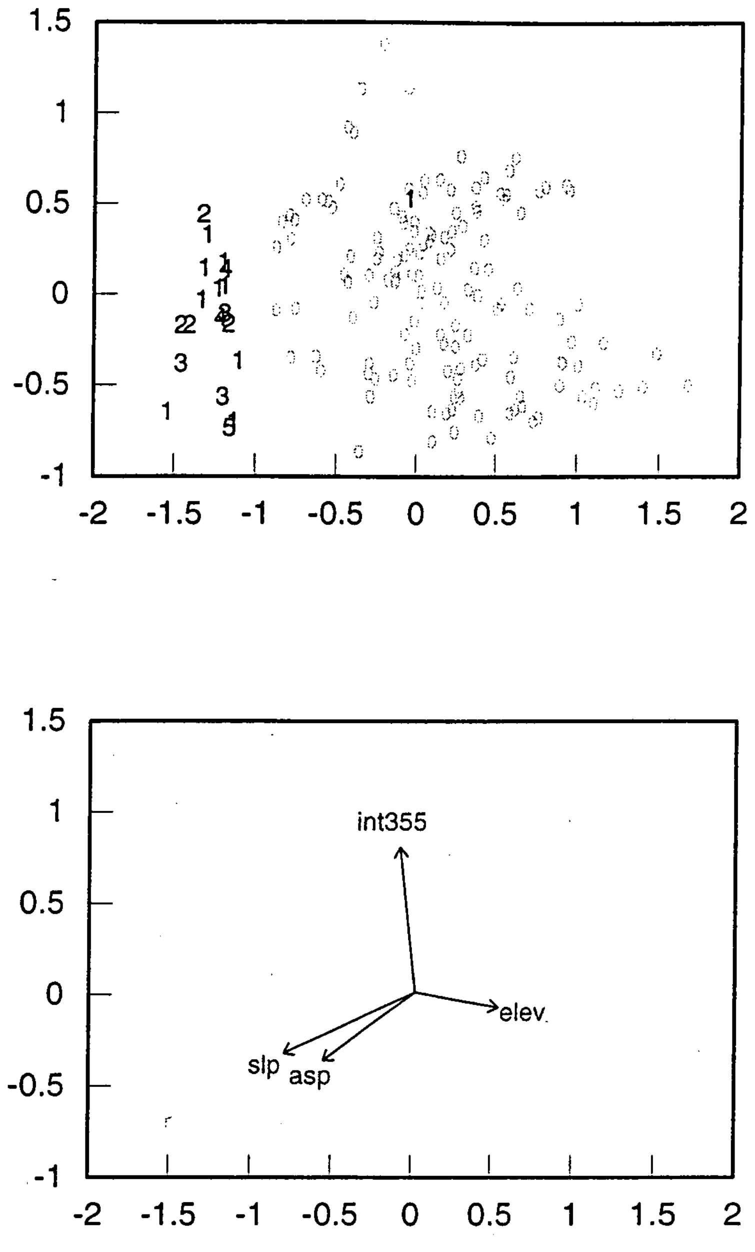


Figure 6.19 upper: Ordination of cape petrel nests (1-4) and inactive cells (0) on Peterson Island; lower, significant variables fitted as vectors in the same ordination space.

The ordination of snow petrels nests and inactive cells on Bailey Peninsula (Figure 6.15) shows that, whereas the inactive cells (zeros) are widespread across the ordination space, the snow petrel nests (from one to three) are distributed in two groups, except for a few isolated nests (five in total). These groups were identified in the univariate analysis as corresponding to northern and southern groups of aspect. The relationship between the nests and the vectors shows that one group is associated with high values of slope, solar intensity and relatively low values of aspect, the other group, by contrast, is associated with lower values of slope, solar intensity and aspect, while the elevation for the two groups remains constant.

The ordination of snow petrel nests and inactive cells on Ardery Island (Figure 6.16) shows that snow petrel nests only occupy a small proportion of the ordination space whereas the inactive cells are widespread. The density of snow petrel nests (from one to four) is continuous with nests associated with low to intermediate values of aspect and slope, and from intermediate to high values of solar intensity and elevation. Sites which have higher values of aspect and lower values of elevation and slope are unoccupied.

The ordination of cape petrel nests and inactive cells on Ardery Island (Figure 6.17) shows that the nests are distributed in three groups. The largest group is associated with intermediate values of solar intensity and elevation, and low values of aspect and slope. The two other groups are associated with moderate values of solar intensity, slope, aspect and elevation.

The ordination of snow petrel nests and inactive cells on Peterson Island (Figure 6. 18) shows that the density of nests (from one to four) and the inactive cells are both widespread across the ordination space. However the nesting sites occupy a smaller proportion of the ordination space than the inactive cells since sites with high values of aspect but low values of solar intensity, slope and elevation have no nests. In constrast, sites with high values of slope correspond to an increase in nest density.

The ordination of cape petrel nests and inactive cells on Peterson Island (Figure 6.19) shows that, in comparison with the inactive cells, the density of nests (from one to three) is remarkably confined to a narrow distribution in the ordination space, with the exception of one nest which was previously identified in the univariate analysis. Nests are associated with high slope and aspect values, low values of elevation and from low to high values of solar intensity. Tables 6.14 and 6.15 below summarise the correlation coefficients of the significant environmental vectors associated with the ordination of each site using the MCAO module in PATN.

Table 6.14: Correlation coefficients of the significant environmental variables associated with the ordination of snow petrel nests at the three sites.

	Bailey Peninsula		Ardery Island		Peterson Island	
variable	**corr. coeff.**	**significance**	**corr. coeff.**	**significance**	**corr. coeff.**	**significance**
slope	0.978	p<0.01	0.945	p<0.01	0.952	p<0.01
aspect	0.504	p<0.01	0.929	p<0.01	0.693	p<0.01
elevation	0.965	p<0.01	0.748	p<0.01	0.975	p<0.01
intensity (day 355)	0.876	p<0.01	0.833	p<0.01	0.84	p<0.01

Table 6.15: Correlation coefficients of the significant environmental variables associated with the ordination of cape petrel nests of Ardery and Peterson Islands.

	Ardery Island		Peterson Island	
variable	**corr. coeff.**	**significance**	**corr. coeff.**	**significance**
slope	0.952	p<0.01	0.705	p<0.01
aspect	0.903	p<0.01	0.95	p<0.01
elevation	0.592	p<0.01	0.957	p<0.01
intensity (day 355)	0.891	p<0.01	0.966	p<0.01

3. Habitat prediction

The habitat prediction is based on the results discussed above. All the environmental variables identified as significant for the selection of a nesting site by snow petrels and cape petrels will be considered in the prediction.

3.1 Habitat prediction for snow petrel nests

Importantly, habitat prediction may differ in accordance with the topographic conditions of each site. In this respect a distinction has to be made between sites with a generally low elevation such as Bailey and Clark Peninsulas and Peterson Island, as opposed to sites with a generally high elevation such as Ardery Island and Odbert Island. This distinction is essential as solar intensity is not a significant variable in the selection of nesting sites on Ardery Island, as this island is only marginally subject to snow accumulation due to its elevation. By contrast,, solar intensity is significant for low elevated areas such as Bailey

Peninsula and Peterson Island, where it facilitated the snow melt.

However, elevation is not considered as an independent variable for habitat prediction since its influence upon the amount of blowing snow and snow accumulation cannot be appraised by the range of elevation values in which nests are distributed. On Bailey Peninsula birds exclusively nest on Reeve Hill but not on similarly elevated areas on the plateau. This suggests that birds select prominent areas within a site and not just elevated areas per se. Such topographic features (i.e. isolated hills) which are less affected by blowing snow are not readily identifiable with GIS and therefore cannot be considered in the prediction.

(i) Low elevated areas: Bailey and Clark Peninsulas, Peterson Island

On Bailey Peninsula, favorable nesting conditions rely upon solar intensity, slope and deviation from the prevailing wind. The deviation from the prevailing wind determines the location of the Northern and Southern groups while the distribution between the northern and southern groups is determined by the intensity of solar radiation. The two groups have a very distinct distribution range for all the significant variables[317]. The northern group contains 60 per cent of the nests while the southern group contains 40 per cent of the nests. The two groups will be used to identify suitable nesting conditions for each significant variable. The distribution range in which snow petrel nests are absent will be used to identify unsuitable conditions. Such distinctions in the distribution range are applied to each significant variable in the prediction. Consequently, an index of suitability for each variable is created with three categories: most suitable, suitable and unsuitable. These categories are intended as representative of the snow petrel habitat for low elevated areas in the Windmill Islands.

Following the results of the univariate analysis, the most suitable category corresponds to the values measured for the northern group of snow petrel nests (ie. slope within the range of 20-50 degrees and deviation from the prevailing

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[317] On the contrary, favorable nesting conditions on Peterson Island rely upon the same variables but these are partially overlapping. The interaction between the intensity of solar radiation and the deviation to the prevailing wind is not as clear as on Bailey Peninsula because of the variations in the positioning of nests to the prevailing wind (calculated from an average of two wind directions). Consequently, the distribution of the snow petrel nests on Bailey Peninsula is used in order to create an index of nesting site.

wind within the range of 30-60 degrees), the suitable category corresponds to the values measured for the southern group (ie. slope within the range of 0-20 degrees, deviation from the prevailing wind within the range of 0-120 degrees), and the unsuitable category coincides with range of values unoccupied by nests. For the intensity of solar radiation, the difference between the values of the northern and southern groups is constant at the four dates. However, on the 31st of January (day 31) there is no overlap between the two groups. This day has therefore been chosen to determine the suitability index. The following index is thus created (Table 6.16).

Table 6.16 : Suitability Index for the habitat selection of snow petrels for low elevated areas (based on the results of the univariate analysis at Bailey Peninsula).

variables	score	group of nests	category
slope			
0-20	1	southern	suitable
20-50	2	northern	most suitable
> 50	0	none	unsuitable
deviation/wind			
0-30	1	southern	suitable
30-90	2	northern + southern	most suitable
90-120	1	southern	suitable
120-180	0	2 nests only	unsuitable
solar intensity (day 31)			
0-3 million W/m2	0	none	unsuitable
3-5 million W/m2	1	southern	suitable
> 5 million W/m2	2	northern	most suitable

An overall suitability index is then applied by adding the score of the three variables for the surface considered. Grids of slope, deviation from the prevailing wind and solar intensity are overlayed in order to obtain a single grid of surface prediction. Surfaces permanently covered by snow are considered as unsuitable.

The northern group coincides with the most suitable category with an index value from 5 to 6, the southern is suitable with an index value from 3 to 4, and the unsuitable category corresponds to an index value from 0 to 2 (two nests only obtain a score of 0).

Table 6.17: Overall Suitability Index for snow petrel nests for low elevated areas (based on the results of the univariate analysis at Bailey Peninsula).

deviation from prevailing wind + slope + solar intensity		
	score	classification
	0-2	unsuitable
	3-4	suitable
	5-6	most suitable

(ii) High elevated areas: Ardery and Odbert Islands

For high elevated sites such as Ardery and Odbert Islands, the intensity of solar radiation is not a significant variable, as shown by the results of the univariate analysis for snow petrel nests on Ardery Island. Slope and deviation from the prevailing wind will be considered as the two significant variables for the prediction. The habitat suitability index will rely upon the distribution of the total number of nests since there is no difference between northern and southern groups for these two variables. For the deviation to the prevailing wind, most suitable conditions will correspond to 80 per cent of the distribution range of the snow petrel nests while suitable conditions will correspond to the remaining 20 per cent of snow petrel nests on Bailey Peninsula. For the slope, most suitable conditions will correspond to 60 per cent of the snow petrel nests distribution on Bailey Peninsula and suitable conditions will correspond to the remaining 40 per cent of the distribution. In both cases, unsuitable conditions will correspond to the distribution range in which snow petrel nests are absent. The following suitability index is thus created:

Table 6.18: Suitability Index for snow petrel nests in high elevated areas (based on the results of the univariate analysis at Bailey Peninsula).

variables	score	% of nests	category
slope			
0-20	1	40%	suitable
20-50	2	60%	most suitable
> 50	0	-	unsuitable
deviation/wind			
0-30	1	10%	suitable
30-90	2	80%	most suitable
90-120	1	10%	suitable
120-180	0	_	unsuitable

An overall suitability index is obtained by adding the score of each significant variable for the surface considered. Grids of slope and deviation from the prevailing wind are overlayed in order to obtain a single grid of surface prediction.

Table 6.19: Overall suitability index for snow petrel nests in high elevated areas (based on the results of the univariate analysis at Bailey Peninsula).

deviation from prevailing wind + slope	
score	classification
0-2	unsuitable
3-4	suitable
5-6	most suitable

3.2 Habitat Prediction for cape petrel nests

As outlined in the discussion of the univariate results, intensity of solar radiation is more important for cape petrels than snow petrels since cape petrels usually have more open nests. Differences between low elevated and high elevated areas have been identified for cape petrel nests as well. In low elevated areas, such as Peterson Island, the importance of solar intensity is greater because of snow accumulation associated with such topographic conditions. However, in high elevated areas, such as Ardery Island, results show that solar intensity is more important for cape petrels than snow petrels and this is reflected by the distribution of cape petrel nests on Ardery Island with 80 per cent of the nests contained within the northern group (which receives the most solar intensity). As solar intensity is important in both low and high elevated sites, its relevance in the distribution of cape petrel nests on Ardery Island can be extrapolated to Peterson Island. Consequently, the same prediction will be applied to low elevated and high elevated sites based on the distribution of cape petrel nests for Ardery Island.

For solar intensity, the distribution range of cape petrel nests on Ardery Island is selected for prediction with only two categories: unsuitable and suitable. The suitable category corresponds to the distribution range of the northern group (80 % of nests) while the remaining 20 % of nests (the Southern group) corresponds to the unsuitable category.

With respect to slope and deviation from the prevailing wind, cape petrel nests on both Ardery and Peterson Islands have the same distribution range. For the slope, two categories have been identified, unsuitable and suitable, with 100 per cent of nests located on Ardery Island falling into the suitable category. The unsuitable category corresponds to the distribution range where no nests occur. For the deviation from the prevailing wind, three categories have been identified: unsuitable, suitable, most suitable. The most suitable category corresponds to 70 per cent of the distribution range of cape petrel nests while the remaining 30 per cent corresponds to the suitable category. The unsuitable category corresponds to the distribution range where no nests occur. The following index is thus created:

Table 6.20: Suitability Index for cape petrel nests (based on the results of the univariate analysis for Ardery Island).

variables	score	% of nests	category
slope			
0-10	0	_	unsuitable
10-40	1	100%	suitable
> 40	0	_	unsuitable
deviation/wind			
0-30	0	_	unsuitable
30-60	1	15%	suitable
60-120	2	70%	most suitable
120-150	1	15%	suitable
> 150	0	_	unsuitable
solar intensity (day 31)			
< 5 million W/m2	0	22%	unsuitable
> 5 million W/m2	1	78%	suitable

An overall suitability index is obtained by adding the score of each significant variable for the surface considered. Grids of slope, deviation from the prevailing wind and solar intensity are overlayed in order to obtain a single grid of surface prediction.

Table 6.21: Overall suitability index for cape petrel nests (based on the results of the univariate analysis for Ardery Island).

deviation from prevailing wind + slope + solar intensity	
score	classification
0-1	unsuitable
2	suitable
3-4	most suitable

3.3. Validation of the suitability index

In order to validate the prediction, the suitability index is applied to Peterson Island, relying upon the assumption that if snow petrels nests obtain a score corresponding to the unsuitable category the index itself would not be valid. However, when applied the index shows that 66per cent of nests are found within the most suitable category and 33per cent of nests are found within the suitable one. No nests correspond to the unsuitable category. This shows that Bailey Peninsula and Peterson Island share the same conditions in terms of unsuitable habitat for snow petrels (which corresponds to scores less than 3).

For Ardery Island, the index was applied to snow petrel nests by adding slope and deviation to the prevailing wind. All the nests are found within the suitable category with a score between 3 and 4.

A qualitative validation of the suitability index is applied to sites for which no GPS positions of nests were recorded. Sketch maps of colonies identified by van Franeker et al.[318] are nonetheless available for Odbert Island. Information compiling faunistic studies undertaken in the Windmill Islands[319] is also available for Shirley Island were snow petrels and cape nests are known to occur.

4. Discussion of the results

4.1 Habitat prediction errors

A measure of the error was calculated in order to test the reliability of the habitat prediction model. The active cells (ie. those containing one or more nests) found in the unsuitable category are considered errors since such cells are expected to fulfill all the habitat requirements identified in the model.

The percentage of error was obtained by dividing the number of active cells found in the unsuitable category by the total number of active cells (i.e. misclassified cells) whilst the percentage of error varies according to the sites and the species considered, as shown in Table 6.22; overall it is less than 10 per cent.

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[318] van Franeker et al., op.cit, supra n° 237.

[319] Murray, M.D., Luders, D.J., op.cit, supra n° 248.

Table 6.22: Percentage of error of the habitat prediction model at sites where nesting positions were recorded.

Location	Percentage of error	
	Cape petrel nests	Snow petrel nests
Bailey Peninsula	–	7.50%
Ardery Island	4%	1.42%
Peterson Island	9.52%	2.41%

A measure of the error could not be generated for the inactive cells since the ones falling into the suitable category correspond to sites which can be potentially colonised by birds in the future, despite containing no nests at present. Alternatively, the cells falling into the unsuitable category are likely to contain no nests since none have been recorded for these cells, but the verification of this hypothesis could only been undertaken in the field, which defeats the very reason for elaborating a habitat prediction model. The purpose of the habitat prediction model is to identify areas which can contain nests without having to undertake extensive field surveys to this end.

4.2 Surface predictions derived from the habitat suitability model

The surface predictions obtained from the habitat suitability model correspond to a large proportion of the surface of each site when including the two categories most suitable and suitable. However, areas falling into the suitable category do not necessary fulfill all the parameters identified as significant for characterising the habitats of snow petrels and cape petrels. If all the environmental parameters identified in the univariate analysis are equally important to define such habitat, it is important that the intervals of values chosen for each parameter coincide with the areas identified as suitable by the model; such conditions are only found in the areas identified as most suitable by the model. It appears therefore that the surface predictions ought to be restricted to the latter category, which is more likely to be colonised by birds. The suitable category provides an indication of where marginal nests may occur but with little chances of breeding success. As Chastel *et al.* note: " finding a free and suitable nest may take a long time and may partially explain the very late age at first breeding of this species"[320].

Even if the most suitable areas are exclusively considered for predicting potential habitats, their actual colonisation by snow petrels, which mainly nest

[320] Chastel, O. *et al.*, op.cit, supra n° 253, p.284.

in crevices, is dependent on the granular disintegration[321] of the terrain, a parameter which could not be incorporated in the model due to insufficient data. This limitation needs to be taken into account in the practical application of the habitat prediction model.

To the extent referred to above, the surface predictions obtained from the model are representative of the coastal ecosystem of Wilkes Land for the two species considered. The practical significance of the surface predictions is to identify areas which could be colonised by the two species in case of an expansion of their population. In fact, the population of both species is expanding in the Windmill Islands[322]. As Woehler and Johnstone note, the population of cape petrels has increased from 90 nests reported on Ardery and Odbert islands in 1962 to 800 nests in 1984. Similarly, the population of snow petrels has increased from 30 nests reported on Ardery and Odbert islands in 1962 to more than 1,100 nests in 1984[323]. In this context, zoning of potential habitats is extremely useful to ensure their preservation against expanding human activities. This is particularly relevant for areas located in proximity of major infrastructures, as illustrated in Figure 6.20 and 6.21 for Bailey and Clark Peninsulas.

On the other hand, this model provides a representativeness value for areas subject to low human interference but for which little bio-physical information is available (e.g. Peterson island). In such a case, the habitat suitability model can be used as a surrogate of a bio-physical inventory. The map of habitat suitability for Peterson Island presented in Figure 6.22 is an example of a decision support tool which can help to determine the status of the island and the degree of protection necessary to protect its ecological integrity.

With respect to Ardery and Odbert Islands, which are already designated as protected areas, the value of habitat suitability maps is to provide an indication of the remaining habitats available for both species, as illustrated in Figure 6.23 for Ardery Island and Figure 6.24 for Odbert Island.

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[321] Granular disintegration is defined by Monkhouse as "the breaking down or crumbling of porous rocks into a granular mass, as a result of freezing following the absorption of water into the pore-spaces". In, Monkhouse, F.J., op.cit, supra n° 235, p.162.

[322] Woehler, E.J., Johnstone, G.W., 1991, Status and Conservation of the Australian Antarctic Territories, In: (Croxall, J.P., ed.) *Seabird: Status and Conservation, a supplement* (Technical publication n° 11), International Council for Bird Preservation, Cambridge, pp. 279-308.

[323] Woehler, E.J., Johnstone, G.W., op.cit, supra n° 322, pp.285 and 287.

Figure 6.20: Predictions of habitat suitability for snow petrels and cape petrels on Bailey Peninsula

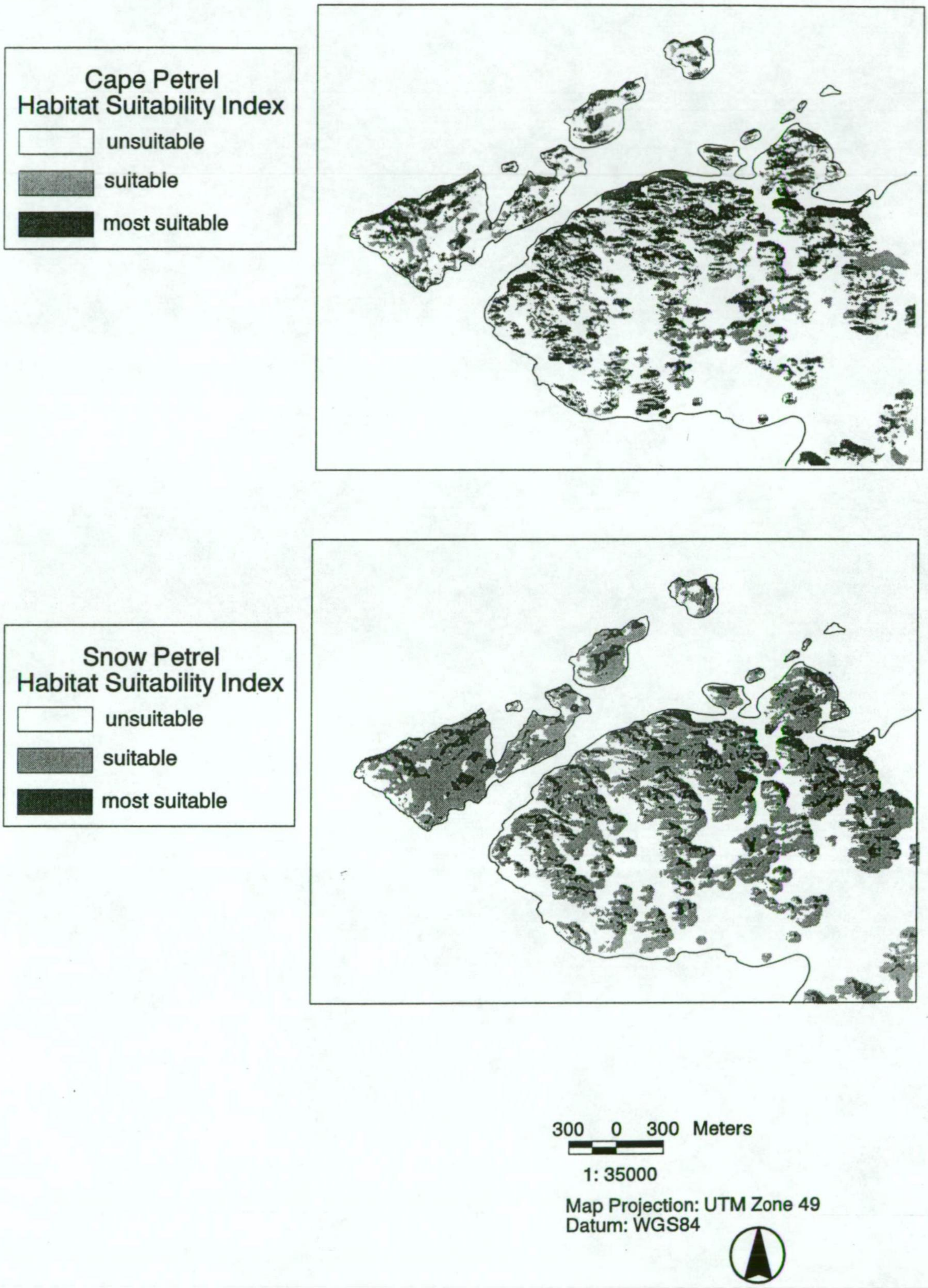


Figure 6.21: Predictions of habitat suitability for snow petrels and cape petrels on Clark Peninsula

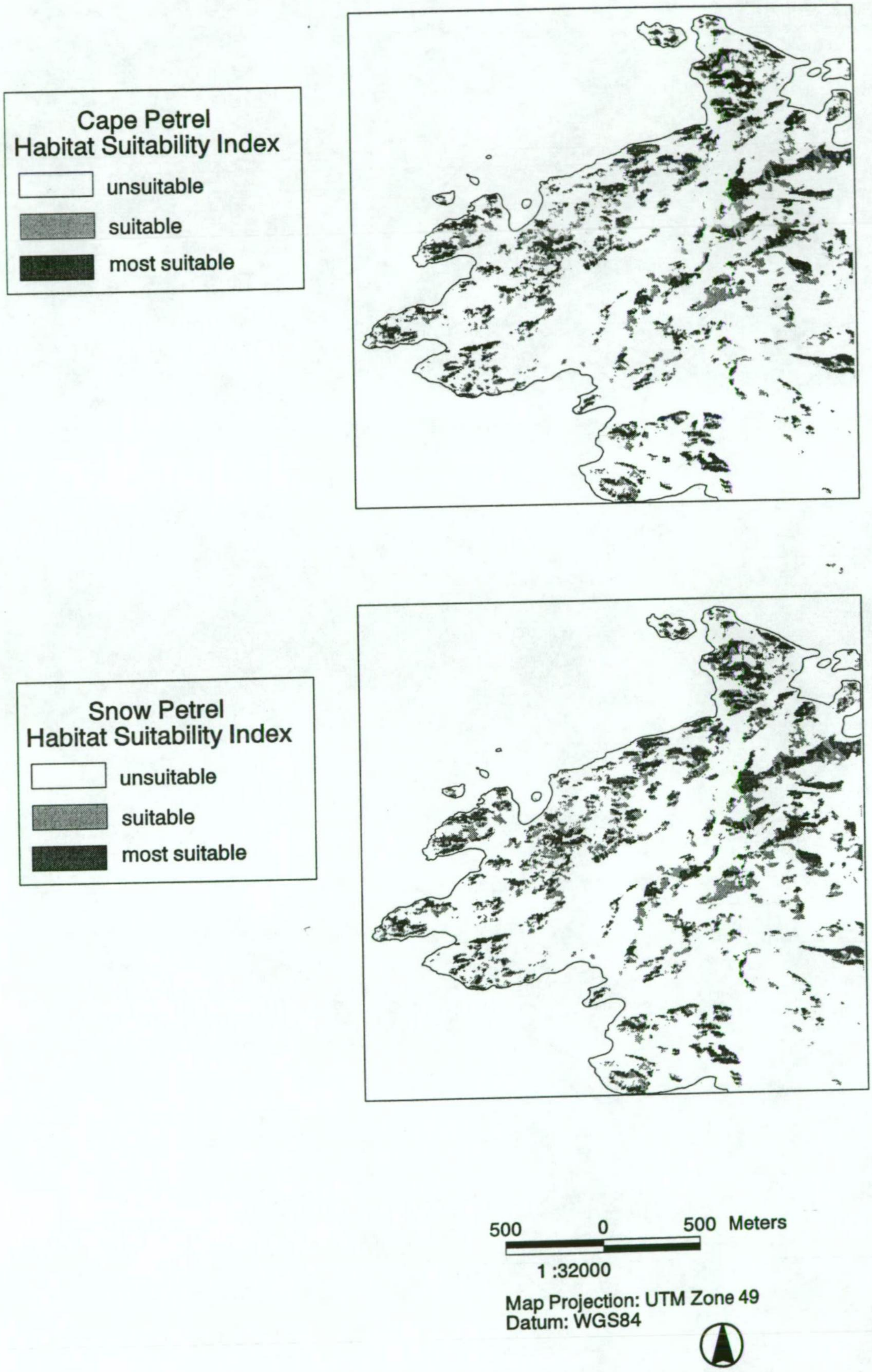


Figure 6.22: Predictions of habitat suitability for snow petrel and cape petrels on Peterson Island

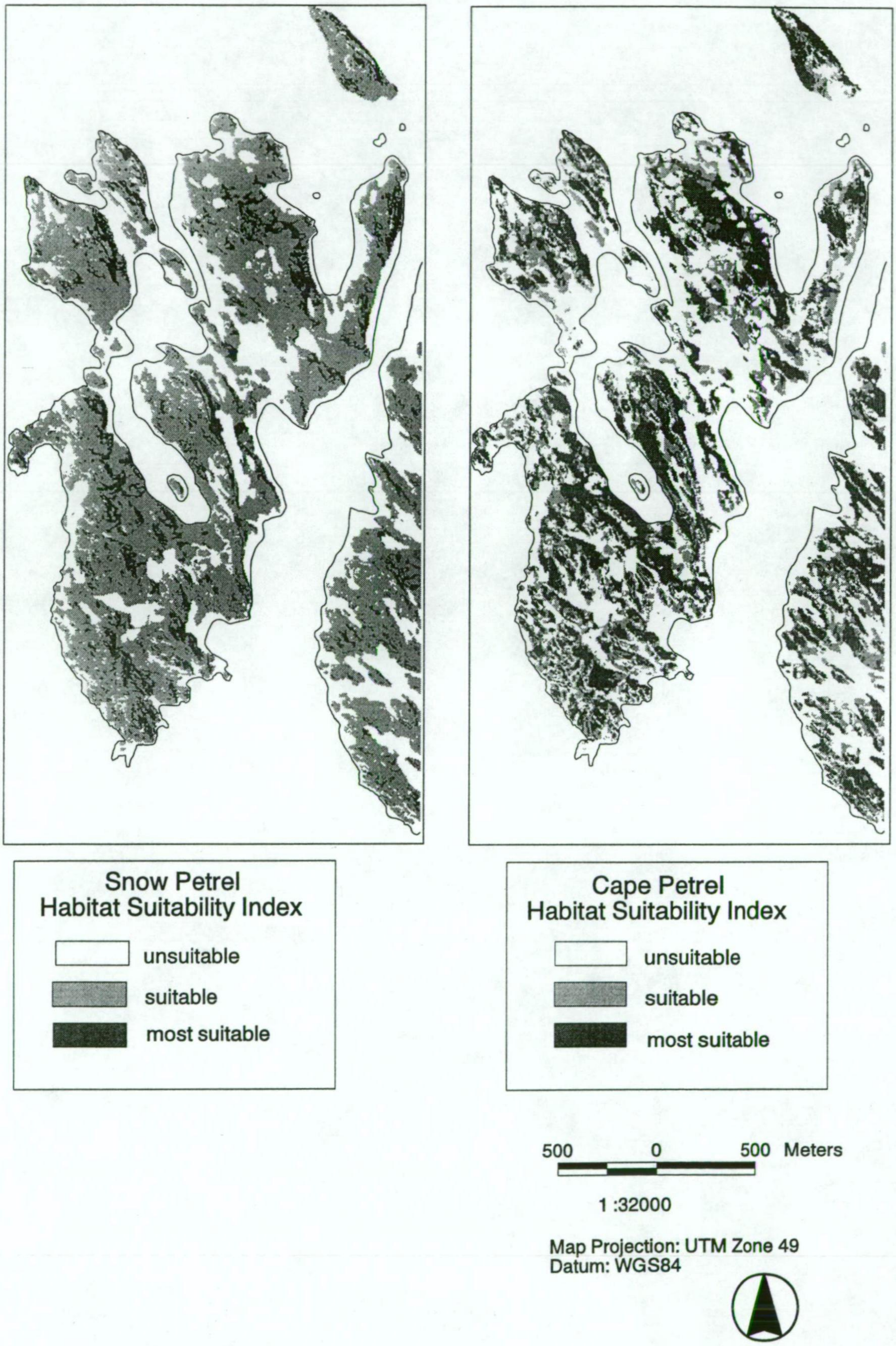


Figure 6.23: Predictions of Habitat Suitability for Snow Petrel and Cape Petrel nests on Ardery Island

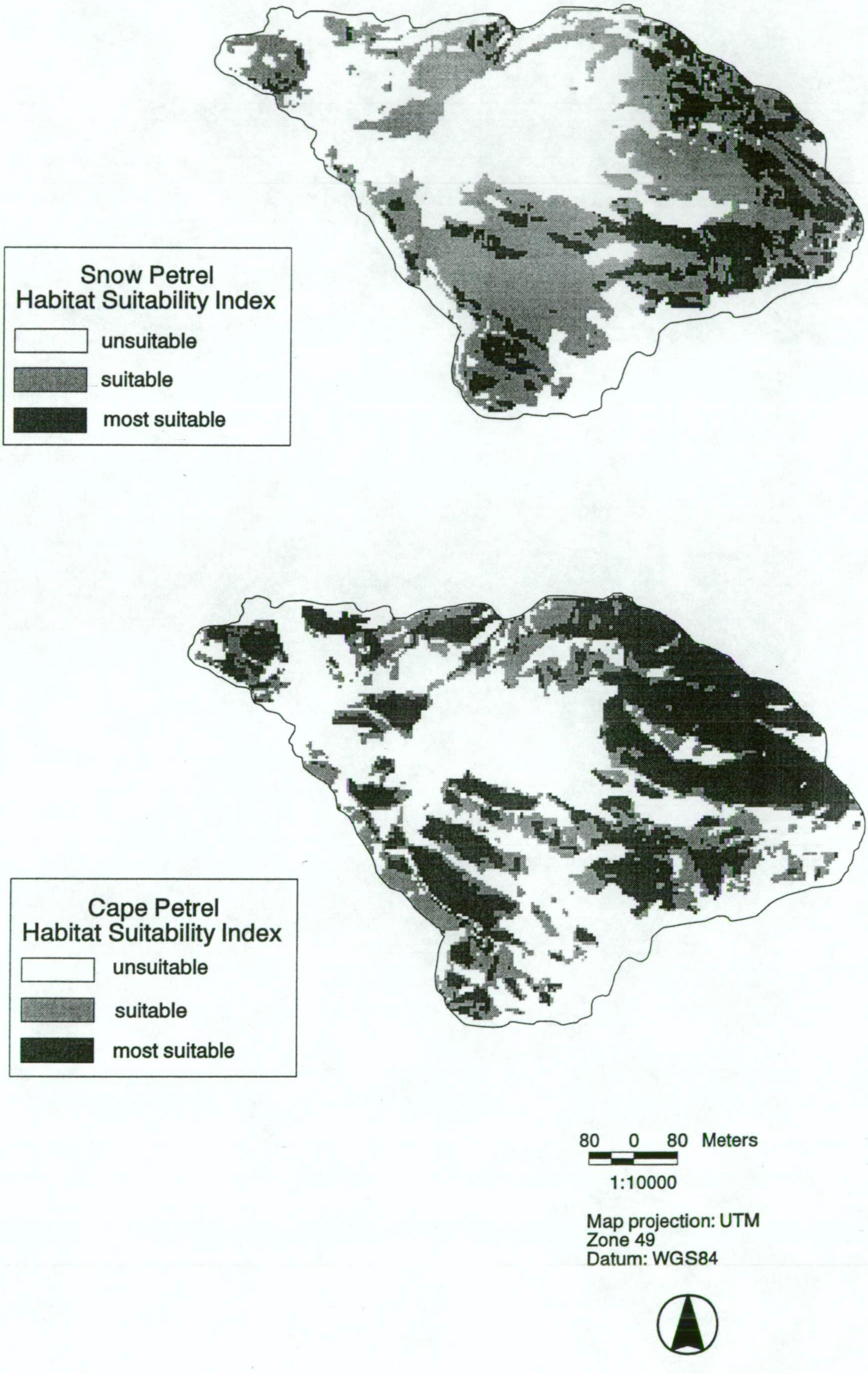
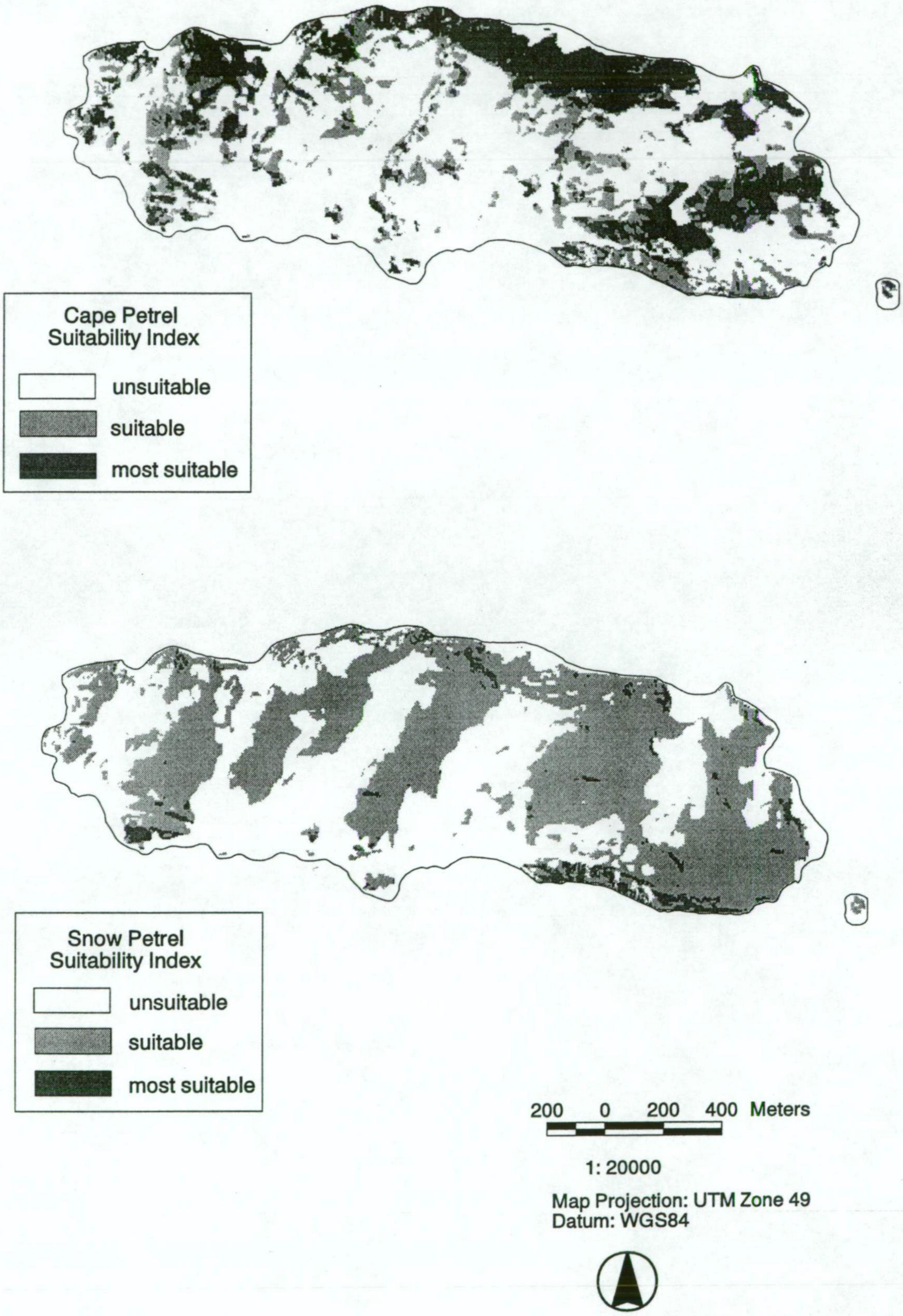


Figure 6.24: Prediction of Habitat Suitability for Cape Petrel and Snow Petrel nests on Odbert Island



5. Assessing wilderness and aesthetic criteria

5.1 Visual Impacts

The GIS methodology described in Chapter V for assessing aesthetic criteria is based on the computation of visual impacts caused by human structures such as buildings and antennas. Such structures are mostly present on Bailey and Clark Peninsulas for which visual impacts were computed using the visibility function of the GRID module of Arc/Info (see Chapter V). Cell values are computed in relation to the type of feature selected as observation points. The output visibility grid identifies areas where the selected features are visible, as opposed to areas from which no features can be seen; it also records the number of features visible for each cell. Cells are classified according to the intensity of visual impact and each class is given a weight as illustrated in Table 6.23. The weighting factor is to be used in the Priority Index in relation to the other criteria (representativeness and wilderness values) .

Table 6.23: Classification of visual impacts

weight	class	description of impacts
0	0	none
5	1	low impact (e.g. one building and/or one antenna
10	2-5	medium impact (e.g. less than 5 buildings and/ or less than 10 antennas)
15	> 5	high impact (e.g. more than 5 buildings and/ or more than 10 antennas)

5.2 Biophysical naturalness

The GIS methodology described in Chapter V for assessing biophysical naturalness is based on the identification of impacts generated by long-term contaminations (e.g. by petroleum products) or soil disturbance (e.g. roads, quarry). Sites containing such impacts are classified within the high impacts category. The contaminated site register established by Deprez *et al.* [324] was used as a reference to digitise contaminated areas on Bailey and Clark Peninsulas. Areas of soil disturbance are restricted to road and parking surfaces

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[324] Deprez, P.P.; Arens, M.; Locher, H., 1994, *Identification and Preliminary Assessment of Contaminated Sites in the Australian Antarctic Territory*, Australian Antarctic Division, Commonwealth Department of the Environment, Sports and Territories, pp. 10-17.

and the zone of the quarry located between Casey station and Reeve Hill. Contaminated areas and areas of soil disturbance are given a weight of 10 points, while areas containing the two types of biophysical disturbance are given a weight of 20 points.

Sites of occasional disturbance to fauna and flora due to logistic and/or scientific and/or recreational activities are classified within the category of medium impacts and given a weight of 5 points. This applies for example to Shirley Island which contains Adelie penguin colonies extensively visited because of their accessibility from Casey station. Table 6.24 summarises the classification of biophysical impacts identified for Bailey and Clark Peninsulas. The weight factor is to be used in the Priority Index in relation to the other criteria assessed.

Table 6.24: Classification of biophysical impacts

Weight	Class	Type of impact	Location (examples)
20	very high impact	contamination and soil disturbance	Old Casey station
10	high impact	long term contamination or soil disturbance	Wilkes refuse area Quarry surfaces occupied by roads
5	medium impact	occasional disturbance to fauna and flora	Casey Station limits Shirley Island
2	low impact	occasional use of an area free of species assemblages	Bailey Peninsula beyond station limits

5.3 Wilderness value

The assessment of the wilderness value is particularly relevant for Ardery, Odbert and Peterson Islands, considering the absence of visual and biophysical impacts recorded on these islands. The wilderness value can be appraised through remoteness indicators which are derived from a definition of wilderness quality elaborated by Lesslie, Taylor and Maslen. Their definition refers to wilderness quality "as the extent to which a location is remote from and undisturbed by the influence of modern technological society"[325]. In this case, the wilderness value is determined by the remoteness from access, defined

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[325] Lesslie, R.; Taylor, D.; Maslen, M.; 1993, *National Wilderness Inventory: Handbook of Principles, Procedures and Usage*, Australian Heritage Commission, p.3.

as the distance from routes and roads and other access facilities; and the remoteness from settlement, defined as the distance from the station and from field huts and refuges. The assessment is based on the frequency and type of access facility along with the type of infrastructure present at each site where access and settlement facilities are made available. Classifications of remoteness from access and settlement are defined in Table 6.25 and Table 6.26.

Table 6.25: Classification of remoteness from access

Weight	Class	Type of access feature
5	very high access	wharf/established road/helicopter landing ground
3	high access	vehicle track ('cane line' route)/ landing access for zodiacs frequently used
2	medium access	vehicle track/landing access for zodiacs unfrequently used
1	low access	ski and/or walking tracks

Table 6.26: Classification of remoteness from settlement

Weight	Class	Type of settlement feature
5	major settlement	station buildings permanently used
3	intermediate settlement	abandoned station buildings and/or filed huts frequently used
1	minor settlement	refuges, field huts, field camps unfrequently used

6. Priority Index

6.1 Method

The aim of the priority index is to assess the relative importance of different areas on the basis of the criteria addressed (i.e. representative, aesthetic and wilderness values). It is entitled priority index as this assessment enables the identification of potential threats and to prioritise areas in accordance with the criteria fulfilled.

As Murray and von Gadow[326] demonstrate in their methodology for

[326] Murray, D.M., von Gadow, K., 1991, Prioritizing Mountain Catchment Areas, *Journal of Environmental Management*, 32, pp. 357-366.

prioritising mountain catchment areas, the emphasis of the priority index is on the development of a decision aid that can be used to determine objectively whether an area has such a management priority that it needs to be protected. In this case study, the priority index is based on a multi-criteria scoring procedure.

Pressey and Nicholls[327] compared the efficiency of scoring criteria (i.e. a priority index) with that of iterative approaches to reserve selection. Iterative methods[328] for reserve selection are designed to identify a relatively small set of complementary sites which contain samples of all known attributes for criteria considered. Their aim is to avoid duplication of reserves containing the same species, communities or habitats in the context of populated areas where private ownership and fragmented habitats impose demands for multiple use access. For example, Kirkpatrick[329] developed an iterative method to assess priorities for the preservation of threatened species in the central east coast of Tasmania. He notes that almost all the remaining native vegetation in the east of Tasmania is found on private land or on land controlled by the Tasmanian Forestry Commission. In such a context, Pressey and Nicholls concluded thus:

> Given the frequent constraints on the number and area of sites available for conservation, the higher efficiencies of the iterative approaches increase the likelihood of achieving the fundamental conservation goal[330].

In this case study, however, it is argued that a scoring approach is the most appropriate method for prioritizing candidate protected areas in Antarctica, given the regulatory framework of human activities contained in the Madrid Protocol. The scoring approach is justified by the fact that competing land uses do not impose the same constraints on protected area designation in Antarctica that apply to populated areas. With the adoption of the Madrid Protocol, competing land uses are meant to be addressed by giving priority to

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[327] Pressey, R.L., Nicholls, A.O., 1989, Efficiency in Conservation Evaluation: Scoring versus Iterative Approaches, *Biological Conservation*, 50, pp. 199-218.

[328] See for example: Bedwart, M., Pressey, R.L., Keith, D.A., 1992, A new Approach for Selecting Fully Representative Reserve Networks: Addressing Efficiency, Reserve Design and Land Suitability with an Iterative Analysis, *Biological Conservation*, volume 62, pp. 115-125.

[329] Kirkpatrick, J.B., 1983, An Iterative Method for Establishing Priorities for the Selection of Nature Reserves: An Example from Tasmania, *Biological Conservation*, volume 25, pp. 127-134.

[330] Pressey, R.L., Nicholls, A.O., op.cit, supra n° 328, p. 216.

environmental conservation. The focus of Annex V is on the development of a planning and zonation scheme that will allow for an improved protected areas system while identifying ecologically sensitive areas threatened by the impact of activities. The aim of such a zonation scheme is therefore to prevent the expansion of human impacts and preserve the ecological integrity of Antarctic ecosystems. Ecological integrity refers to the condition at sites with little or no influence from human actions; that is, the resident biota is the product of evolutionary and biogeographic processes at a site[331]. As Westra notes:

> If all aspects of managed human activity within ecosystems gain their life support and their sustainability, hence their very identity, from areas of integrity, then we must learn to manage and limit human activities in harmony with this basic reality[332].

In this context, the scoring method of the priority index provides an indication of the state of the environment which can support planning decisions. The priority index is therefore relyiant upon what Westra describes as the "integrity paradigm"[333], wherein competing land uses should be understood in the context of the primary necessity of large wilderness preservation. In this sense, the priority index can be opposed to iterative approaches to reserve selection for which ecological criteria are to be weighted against competing developmental, economic or social claims.

The scoring method weights the representative value of a given area against the human impacts in order to identify priority areas; these correspond to areas fulfilling the representative criteria while remaining non-impacted.

The representative value is obtained by adding the weights and overlaying the surfaces corresponding to the most suitable habitats for snow petrels and cape petrels. Areas covered by vegetation are given the same weight and overlayed with the most suitable habitats for snow petrels and cape petrels.

The sum of all human impacts is obtained by adding the weighted scores of the

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[331] Karr, J.R., 1994, Landscapes and Management for Ecological Integrity, In: (Cambridge University Press, ed.) *Biodiversity and Landscapes: A Paradox of Humanity*, Cambridge: Cambridge University Press, pp. 227-249.

[332] Westra, L., 1995, Ecosystem Integrity and Sustainability: The Foundational Value of the Wild, In: (Westra, L., Lemons, J., eds.) *Perspectives on Ecological Integrity*, Dordrecht: Kluwer Academic Publishers, p. 16.

[333] Westra, L., op.cit, supra n° 332, p.16.

visual and biophysical impacts to the weights of the remoteness indicators; the surfaces of impacts are also overlayed. The score for the human impacts is then subtracted from the representative value of a given area.

The priority index (PI) corresponds to the following formula:

$$PI = R - HI$$

where R = most suitable habitats for cape petrels and snow petrels + vegetation and HI = (visual + biophysical impacts) + (remoteness from access + remoteness from settlement)

6.2 Results

The scores of the case study sites range from -60, corresponding to the non-representative impacted cells to +2, corresponding to non-impacted and representative cells. Table 6.27 summarises the percentage of cells contained within eight classes of the priority index for each site. The classes range from low (cells inferior to -25) to high priority (cells superior to 0) with intermediate classes (from -20 to -4).

Table 6.27: Percentage of cells per priority class for each site

Classes	Bailey Pen.	Clark Pen.	Peterson Isl.	Odbert Isl.	Ardery Isl.
< -25	13%	_	_	_	_
< -20	32.30%	_	_	_	_
< -16	30.40%	0.70%	_	_	_
< -12	10.30%	0%	_	_	_
< -8	13%	8.50%	_	_	_
< -4	0.90%	81.30%	_	_	_
< 0	_	9.50%	89.90%	98.20%	89.50%
1	_	_	10.10%	1.80%	10.50%

Figure 6.25 provides a cartographic output of the results at the scale of the Windmill Islands region: it indicates that the low priority areas are concentrated on Bailey Peninsula, and to a lesser extent on Clark Peninsula. The areas of highest priority are situated in the southern part of the Windmill islands.

Figure 6.26 and Figure 6.27 identify priority areas for Bailey and Clark Peninsulas through different shading levels, with impacted areas (in dark) and gradients of pristineness and representativeness (from grey to white) for areas subject to lower impacts.

With respect to Bailey Peninsula, Figure 6.26 shows the extent of the station impacts, with priority areas located at the periphery of the peninsula, such as Reeve Hill, adjacent to Casey station, and Shirley Island which is accessible most of the year from Bailey Peninsula by sea-ice. Whereas most of the vegetation communities of the peninsula are protected within the area of SSSI n° 16, Reeve Hill has not received formal protection yet despite the presence of a snow petrel colony. Most of Shirley Island is also identified as a priority area but has received no formal protection yet; part of the island is visually impacted by the station and these areas have been successfully modeled by GIS. The island contains areas identified as most suitable habitats for snow petrels and cape petrels, and snow petrel nests are present on the island. Of all the remaining representative areas on Bailey Peninsula, Reeve Hill and Shirley Island clearly appear to be priority zones for which specific management action should apply.

With respect to Clark Peninsula, Figure 6.27 shows the extent of impacts, which are confined to a small proportion of the peninsula. The remaining area coincides with SSSI n° 17, which received protection because of the presence of vegetation communities. The area also include representative habitats of snow petrels and cape petrels as identified previously. The priority areas identified for Clark Peninsula therefore do not require further protection, except for the areas outside SSSI n° 17 which may be considered as part of a rehabilitation plan considering the extent of refuse disposal areas and the likelihood of soil contamination by the presence of fuel drums stored in such areas.

With respect to Ardery, Odbert and Peterson Islands, a common characteristic is the absence of human impacts, with the exception of access and settlement features. Ardery and Odbert islands are both protected areas and the priority areas they contain consequently do not require further protection. On the contrary, the priority areas identified on Peterson Island coincide with a large proportion of the island. No vegetation data has been recorded and priority areas therefore correspond to most suitable habitats for snow petrels and cape petrels (see Figure 6.28). Given the extent of the identified priority areas, Peterson Island ought to be considered as a candidate protected area.

Figure 6.25: Priority Index of the case study sites of the Windmill Islands.

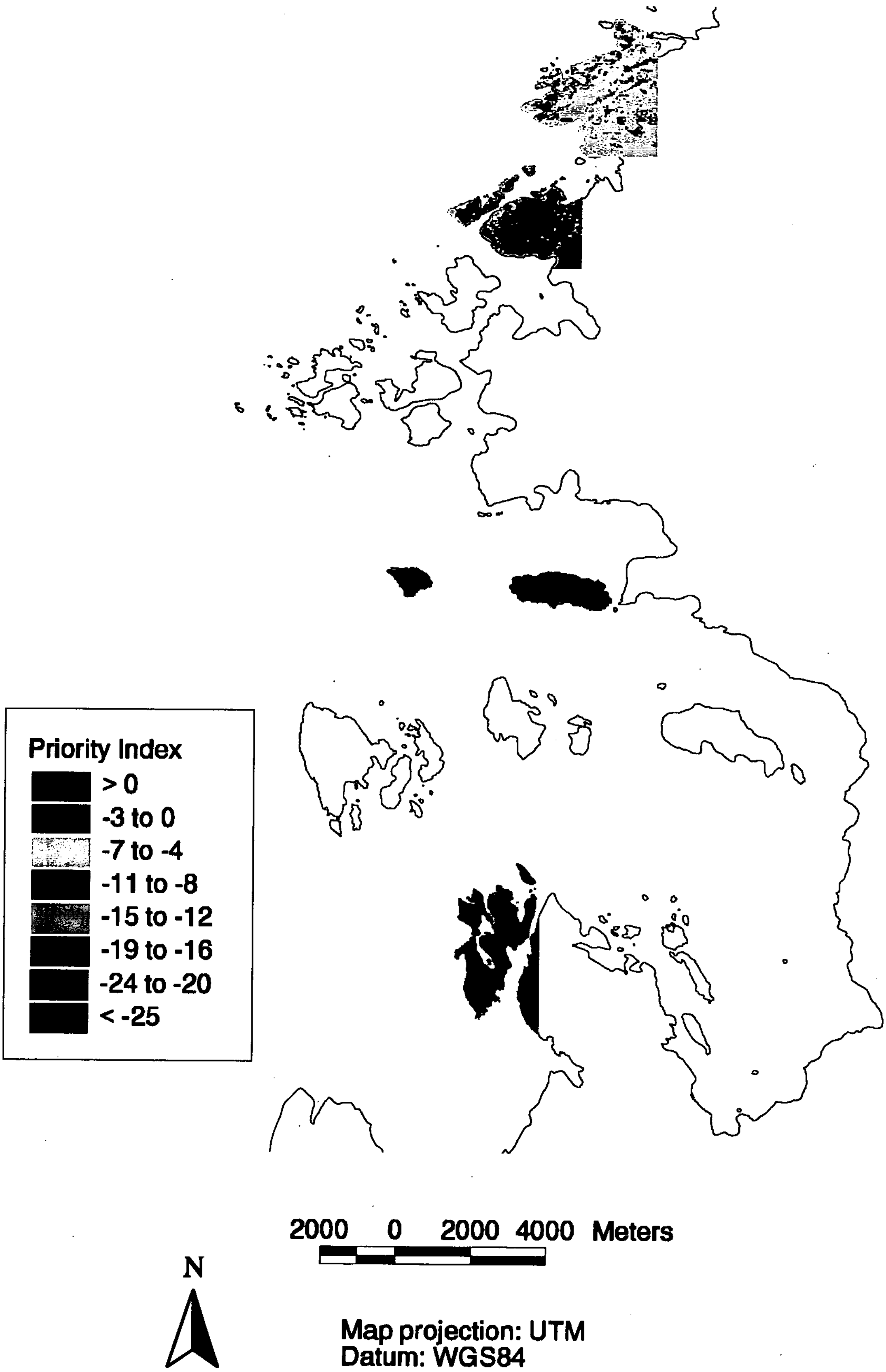


Figure 6.26: Priority Index of Bailey Peninsula

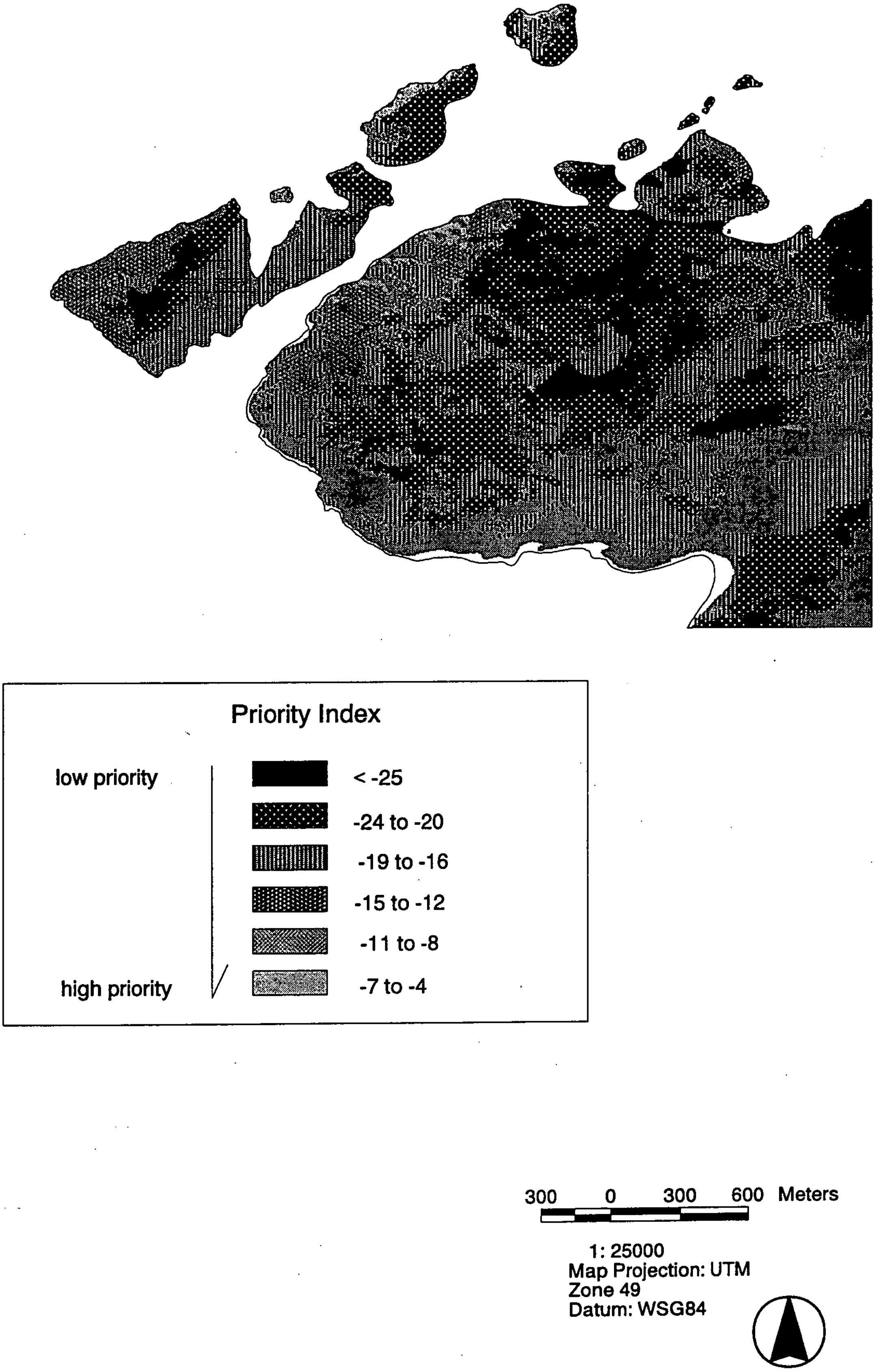


Figure 6.27: Priority Index of Clark Peninsula

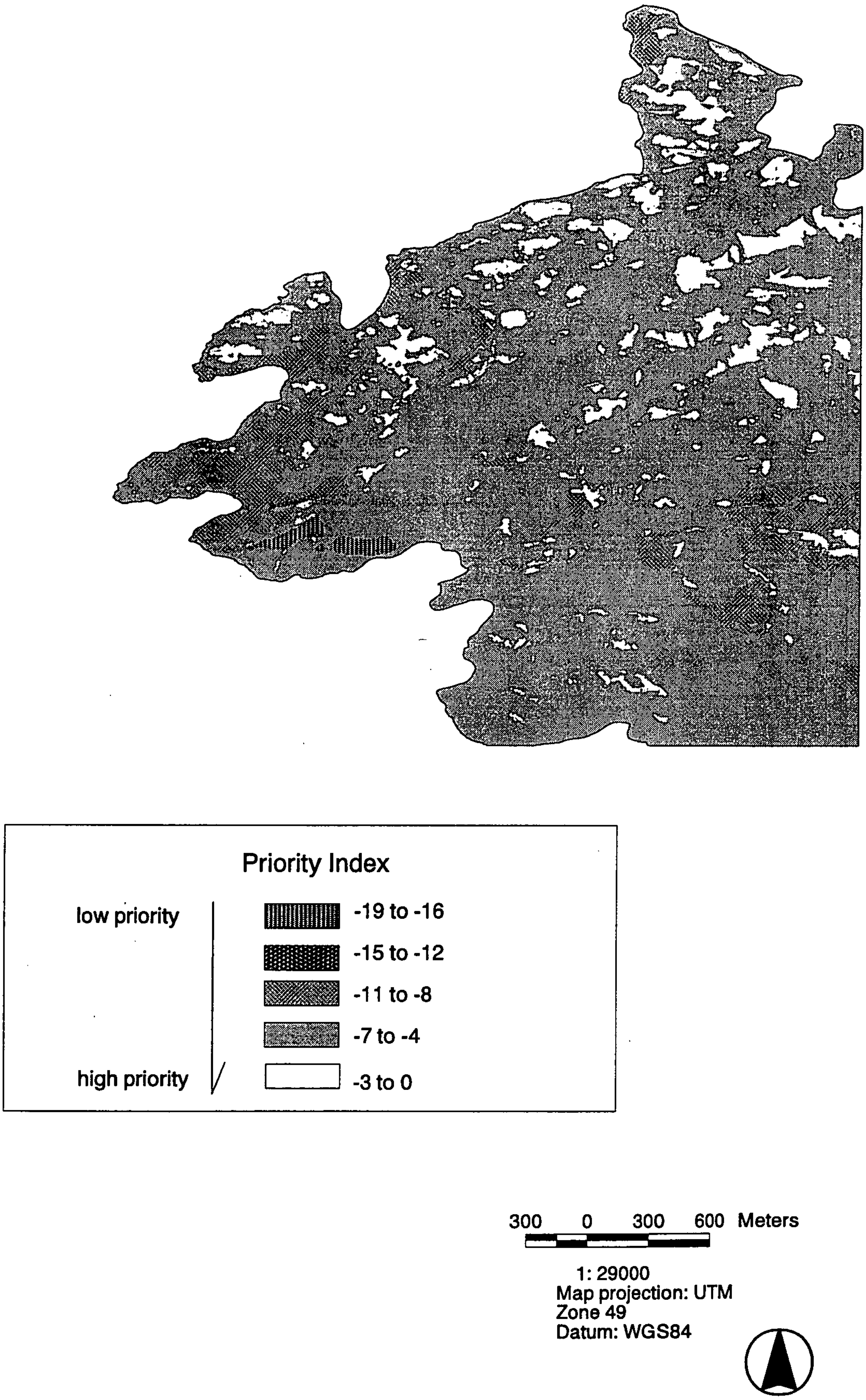
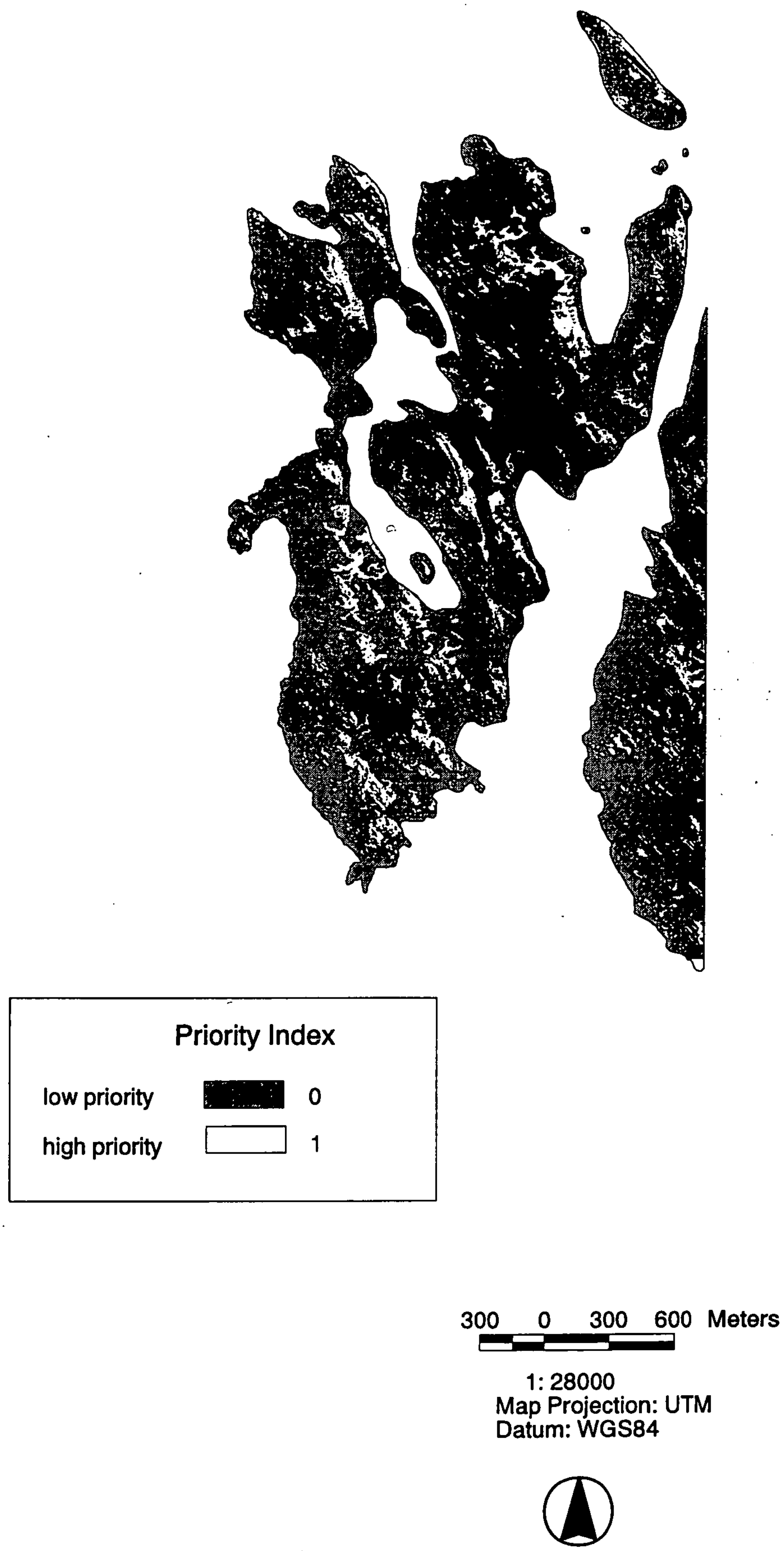


Figure 6.28: Priority Index of Peterson Island



6.3 Future Considerations

The purpose of the case study was to demonstrate techniques for identifying species habitat in the absence of detailed survey data. This would provide biological data for the priority index. The model can be improved through availability of data on other criteria. For example, the priority index would integrate a biodiversity value, providing a more detailed inventory of the species was available for the case study area. The representative value also ought to incorporate habitat suitability for all the species known to occur in the case study area. This would be relevant for areas such as Shirley Island and Peterson Island which both contain Adelie penguin rookeries while Peterson Island contains several elephant seal haul-out sites. Other species can be incorporated in the model using the methodology developed here.

The priority index might be further elaborated by incorporating criteria listed in Article 2 of Annex V which have not been considered in this case study; These are: rarity (i.e. "the type locality or only habitat of any species"), uniqueness (i.e. "examples of outstanding geological, glaciological or geomorphological features"), historic and scientific values.

The priority index has only been applied to the five sites selected for the case study. In the future, the priority index ought to be applied to all the Windmill Islands region so that the relative importance of each site could be compared in accordance with the criteria fulfilled.

The above limitations need to be addressed before the priority index could be used as a practical outcome for zoning and environmental management purposes.

7. Conclusion

The priority index integrates three of the criteria listed in Article 2 of Annex V for protected area designation. Considering the review of the Antarctic protected area system elaborated in Chapter III and the critique of the sporadic designations which prevailed until the adoption of the Protocol, representativeness appears to be the most important criterion to implement. In this respect, the methodology for assessing the representativeness of biophysical sites successfully characterised and predicted the habitats of snow petrels and cape petrels. These results consequently facilitate a precise localisation of representative areas which ought to be integrated in the existing framework of protected areas and in the planning and management of human activities. Indeed, the increase of population for the two seabird species in the Windmill Islands provides a strong argument for selecting additional protected areas on the basis of representative habitats.

The cartographic outputs illustrate priority areas at the scale of the Windmill Islands, locating the most impacted areas in the northern part of the region and areas of high ecological integrity in the southern part. Priority areas are also located within each site. This is particularly relevant in areas where human impacts are concentrated (such as Bailey and Clark Peninsulas) since the combined assessment of biophysical and visual impacts allows for their precise delimitation. Representative zones contained within such areas, although impacted, are also identified and can be incorporated as sensitive areas within future management plans.

Despite limitations in terms of criteria, sites and species considered, the results of this case study demonstrate the potential of the GIS methodology as a tool for modelling the impacts of future developments and for monitoring the expansion of human activities in order to preserve the ecological integrity of the region considered. The loss of representativeness in both instances can be assessed using the priority index. This methodology would facilitate a pro-active management of human impacts and could be applied to other ice-free areas within the same bio-region, such as Pointe Geologie Archipelago in Adelie Land.

Chapter VII

Conclusion: Implications of the Research Findings and Recommendations

The first part of this thesis analysed legal and policy issues associated with the implementation of the Madrid Protocol (Chapter I). The lack of provisions regarding the collection, processing and analysis of environmental information prior to decision making has been assessed in the light of the difficulties experienced by CCAMLR. A comparison of these two instruments revealed the institutional weakness of the provisions contained within the Madrid Protocol and the absence of information tools made available to the CEP in order to fulfill its advisory role (Chapter II).

The second part of the thesis demonstrated the benefits of developing an information management strategy wherein GIS would play a central role as a decision support tool for the operation of the CEP. The relevance of using GIS was highlighted for implementing the provisions contained in Annex V of the Madrid Protocol concerning area protection and management (Chapter III). Further argumentation for the use of GIS was provided regarding the role of the CEP in the operation and development of the new protected area system along with the recommendations this advisory body will be adopting with respect to environmental impact assessment and monitoring procedures (Chapter IV).

The third part of the thesis demonstrated through a case study how GIS could be used to implement the criteria for identifying protected areas listed in Annex V of the Protocol. A methodology for interpreting and applying such criteria with GIS was elaborated (Chapter V). The applicability of this methodology has been tested for the representative, wilderness and aesthetic criteria, showing the relevance of using GIS for identifying areas fulfilling such criteria (Chapter VI).

The research findings of the third part of the thesis therefore support the theoretical arguments advocating the need for GIS as an implementation tool of the Madrid Protocol which were developed in the first and second parts. This concluding chapter will outline the broader implications of the research findings and the preliminary conditions to an effective use of GIS within the CEP. Finally, recommendations will be made for implementing the Madrid Protocol within the framework advocated in this thesis.

1. Implications of the Research Findings

The most important implication of the research findings concerns the improvement in the environmental decision making process which the use of GIS has potential to bring to the ATS. As analysed in Chapter III, the Madrid Protocol introduces a new legal framework for environmental protection which is in essence pro-active. However, the implementation of such a pro-active approach requires changes in the environmental decision making process and a number of adjustments in the past environmental practices of ATPs. Addressing these two issues presents uneven difficulties since the adjustments of past environmental practices are undertaken as part of the ratification process which is about to be completed for all ATPs[334]. Addressing the issue of change in the environmental decision making process is more complex since it refers to the political willingness of Treaty Parties to recognize the current limitations of the ATS for ensuring a standardized implementation of the Madrid Protocol. Furthermore, it also implies that Treaty Parties would have to recognize the potential benefits of using decision support tools such as GIS on a continental scale for improving the operation of advisory bodies such as the CEP. The different tasks assigned to the CEP (ranging from environmental monitoring and environmental impact assessment to environmental protection) emphasize the responsibility of this body for coordinating and supervising a standardized implementation of the Madrid Protocol among all Treaty Parties. But, as argued before, the Madrid Protocol remains silent as to how the implementation of such changes in the environmental decision making process will be promoted. The aims of this thesis were to investigate means of introducing such changes within the framework of the CEP.

The research findings focused on demonstrating the relevance of the use GIS to implementing the criteria listed in Annex V for identifying potential protected areas. The case study examined only terrestrial ecosystems due to current limitations in terms of data availability. Amongst them, representative areas of suitable habitats for two important species of seabirds were identified. The GIS methodology elaborated could be extended to all the criteria listed in Annex V, including an assessment of representative areas for other biota such as vegetation, seals and other breeding species of seabirds. The development of such a methodology entails a long term investment of staff and resources. This is likely to create difficulties for Treaty Parties which do not have the financial

334 At the last ATCM in 1997, Japan and Russia were the last Treaty Parties to ratify the Madrid Protocol.

capacity to establish and operate a GIS programme. The creation of the Antarctic Master Directory (AMD) hosted by ICAIR in New Zealand has the potential to overcome such difficulties. The United States, New Zealand, Italy and France have agreed to provide a financial contribution along with environmental data to the AMD. It is essential that all Treaty Parties participate in such a cooperative agreement in order to reduce the costs of establishing a GIS database of their own. Once this is achieved, the CEP could then access the data contained in the GIS database of ICAIR and specify additional requirements in terms of data collection so that it could implement the criteria for protected area designation listed in Annex V using the methodology developed in the case study. The type of analysis that the CEP would be able to undertake with GIS extends the scope of protected area designation. For example, it could encompass a review of environmental impact assessment[335] and environmental monitoring procedures and reporting to the ATCM on the state of the Antarctic environment. The major obstacles to be expected would be stem from limitations upon financial and staff resources and on the political willingness of Treaty Parties to let the CEP effectively review the implementation of the environmental procedures described in the Madrid Protocol. As Kraemer remarks:

> Technology-related reforms depends on the congruence of proposed uses of information technology and the interests of the existing power structure. Use must reinforce the interests of the existing power structure, or the reform will not happen[336].

The effective use of GIS in the context described above requires a number of preliminary conditions to be fulfilled. These are discussed in the following section.

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[335] For examples of GIS applications in Environmental Impact Assessments, see: Guariso, G., Page, B., eds., 1994, *Computer Support for Environmental impact Assessment*, North-Holland: International Federation for Information Processing, 320 pages.

[336] Kraemer, K.L., 1991, Strategic Computing and Administrative Reform, In: (Dunlop, C., Kling, R., eds.) *Computerization and Controversy: Value Conflicts and Social Choices*, San Diego: Academic Press, p.178.

2. Preliminary Conditions to an Effective Use of GIS by the CEP

The research findings of Campbell and Masser[337] with respect to the use of GIS in British local government indicate three areas that need to be considered if effective utilization is to be achieved. These are:

- an ability to cope with change

- a commitment to and participation in the implementation of the system by individuals at all levels of the organization, and

- an information management strategy that identifies the needs of users and takes account of the resources and values of the organization[338].

These issues will be examined in the context of the ATS and of the role of the CEP.

(i) Ability to cope with change

The introduction of GIS as a decision support tool available to the CEP has implications in terms of change in the decision making style and in the value of the information used to support decision making. The adoption of GIS technology relies upon the assumption that GIS provides better information which can rationalize the decision making process. As Zwart notes:

> Better information will, therefore, be interpreted as information that is more reliable, accurate, current, complete and delivered in a more timely manner because an integrated land information systems has been created. A better decision will be interpreted as meaning a decision that is more consistent, more rational and more efficient because of the availability of better information[339].

The rationalization of decision making provided by GIS also implies that policies will emerge based on the same criteria, since GIS databases incorporate,

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[337] Campbell, H; Masser, I., 1995, *GIS and Organizations: How Effective are GIS in Practice,* London: Taylor & Francis. 178 pages.

[338] Campbell, H., Masser, I., op.cit, supra n° 337, p.45-46.

[339] Zwart, P., 1988, Some Observations on the Real Impact of Integrated Land Information Systems upon Public Decision Making in Australia, *Proceedings of URISA 1988,* Los Angeles, August, vol.1, p.70.

manipulate and graphically display data which can be used for the identification of criteria such as wilderness or representativeness for example. Decision makers may not agree on the relative importance or weight attached to each particular value, but the ability of GIS to portray and replicate these values (which have legal standing in accordance with the criteria listed in Article 3 of Annex V) for different areas removes the opportunity for arbitrary decisions to be taken.

The question remains whether Treaty Parties are ready to accept such a change in the style of decision making. The latter previously relied upon negotiating processes rather than readily quantified criteria and methods in order to arrive at acceptable solutions.

(ii) Commitment to and participation in the implementation of the system by individuals at all levels of the organization

If GIS facilities become available to the CEP, its implementation will necessarily involve sharing information with other Antarctic organizations possessing GIS databases. The social and political implications of GIS thus need to be considered. As Campbell and Masser remark, "the conceptualization of GIS implementation as a social and political process is crucial. This shifts the focus of attention from the technology to the organization"[340]. This observation emphasizes the issue of sharing information between the CEP and various organizations such as national Antarctic programs and ICAIR. Indeed, the theoretical advantages of sharing information (i.e. reducing duplication and achieving more informed decision making) may provoke counter-implementation reactions if individuals feel that it will lead to closer supervision of their activities or open up the decision making process to greater scrutiny. This is particularly relevant in the case of national Antarctic programmes and their planning which have been subject to little scrutiny until now.

When it comes to ensuring commitment to and participation in the implementation of GIS by the members of the CEP, such conditions are likely to be fulfilled as the CEP has not yet been provided with any means of operation yet. That is to say, the introduction of GIS is unlikely to encounter resistance stemming from working traditions as the CEP will only become operational once the Madrid Protocol comes into force. However, there are a number of

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[340] Campbell, H., Masser, I., op.cit, supra n° 337, p.158.

practical considerations concerning the elaboration of an information management strategy, and these are examined below.

(iii) An information management strategy identifying the need of users and taking into account the resources and values of the organization

As Campbell and Masser remark, it is the users themselves who have the fullest appreciation of their requirements, and therefore it is vital that they take a central role in both the preparation of the initial information management strategy and system implementation, if commitment is to be secured[341]. This implies that users must be fully aware of GIS capabilities and receive appropriate forms of training. Users need to be able to identify the types of information that are essential to the operation of the organisation. Staff must understand the information priorities of the CEP and the contribution of GIS technology to the achievement of its goals. For this, there must be a link between the potential information to be generated by GIS and the essential needs of the CEP.

The resources necessary to secure utilisation need to be taken into consideration as well, since most GISs need a considerable level of customization to become operational. The composition of the CEP should therefore include skilled systems analysts and programmers along with experts in environmental conservation and management in Antarctica. Training is particularly relevant in the case of the latter category if effective implementation of GIS is to be achieved by the CEP. As Baskerville notes:

> The introduction of Geographic Information Systems is a teaching-learning experience for both the GIS technocrats, and for those in the decision making process who would use the technology as a decision aid. It is necessary for the GIS technologist to learn something of the environment of decision making. It is necessary for the people in the decision making process to teach those in GIS the role of geographic information as it exists in the decision context[342].

The information management strategy aims at anticipating the type of data and analysis required for an effective implementation of GIS within the advisory role assigned to the CEP. It ought to answer the following questions:

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[341] Campbell, H., Masser, I., op.cit, supra n° 337, p.135.

[342] Baskerville, G.L, 1991, GIS and the Decision Making Process, In: (Heit, M., Shortreid, A., eds.) *GIS Applications in Natural Resources*, Colorado: GIS World, p.4.

- How much support could information systems give and for what category of issues?
Potential applications of GIS within the CEP have been outlined in chapters III and IV of this thesis. These range from environmental management and monitoring to environmental impact assessment procedures. GIS applications would firstly provide a systematic and independent review of the implementation of such procedures within the Protocol; secondly they would enhance the capacity of the CEP to improve such procedures and the advice delivered to ATCMs.

- How, and under what circumstances, is the information used?
The information generated with GIS would be used for supporting the recommendations formulated by the CEP with respect to the implementation of the Protocol. This would be particularly useful once discrepancies between national policies set up for implementing the provisions of the Protocol have been identified. For example, the methodology described in chapter V could be applied for the identification of significant biophysical areas deserving protected area designation. This methodology would be useful for identifying gaps within the protected area system of Antarctic jurisdictions.

- How much and what type of data should the system contain in order to provide the requisite support?
If the data sharing formula described above is accepted, access to metadata[343] should be guaranteed by organisations such as ICAIR. The following datasets would be required: topography, human infrastructures, human impacts, fauna and vegetation. Ideally such data would need to be available for all the operational areas in Antarctica, particularly the surroundings of stations.

- How much information and in what form should the system deliver?
Once a customisation of GIS is achieved, the CEP should be able to select priority areas for which a review is required. Reviews would be conducted in collaboration with Antarctic Treaty Party concerned, especially if additional data needs to be collected. The outcome of such reviews would vary according to the topic. Maps would be generated as outputs along with a presentation of

[343] Metadata can be described as "digital information that allows the potential user of spatial data to understand the data's fitness for use. Components of such metadata might include information on database contents, database schema, its source and history, and quality". For further information on this issue, see: Onsrud, H.J., Rushton, G., 1992, *Institutions Sharing Geographic Information,* Technical Report 92-5, National Center for Geographic Information and Analysis, USA, p.12.

the results on the basis of which recommendations would be formulated. Reviews of implementation procedures would be undertaken case by case, following requests from ATCMs or from individual Treaty Parties. Importantly, a standard methodology would be applied to each of the cases considered.

In constructing an information strategy for the CEP, it has become clear that few, if any, of the conditions described above are currently being fulfilled. This applies particularly to the amount and type of data required for the requisite GIS support. The following section will therefore detail a number of recommendations which need to be considered if GIS is to become effective within the framework of the CEP.

3. Recommendations

(i) The collection of environmental and human impacts data

The issue of data collection is essential as it determines the feasibility of all GIS applications. It is therefore recommended that ATPs undertake a systematic biophysical inventory of the resources contained within their jurisdiction so that these can be available in a GIS format. Data collection using GPS is recommended as a cost-effective technique requiring limited personel in the field. Similarly, human features and human impacts ought to be systematically surveyed and readily available in a GIS format.

(ii) Institutionalisation of the CEP and means of operation

It is recommended that the issue of providing the CEP with effective means of delivering advice on environmental issues should be discussed at future ATCMs. This issue is linked to the institutionalisation of the CEP as a permanent body provided with a secretariat and permanent staff. The potential use of GIS as a decision support tool for the CEP would be an important agenda item given the relevance of GIS in this context, as evidenced throughout this thesis.

(iii) The elaboration of a strategic plan identifying the priority tasks of the CEP

Considering the wide range of activities for which the CEP will be required to deliver advice (review of environmental impact assessment procedures, environmental monitoring schemes, environmental management of human impacts, development of the protected area system) it is essential for its appointed members to prioritise their action through the elaboration of a strategic plan. The priorities defined in the strategic plan need to be discussed and approved at ATCMs along with the methods and techniques required to achieve the goals set in the strategic plan.

(iv) GIS pilot studies within the CEP

It is recommended that GIS prototype projects be developed within the CEP so that the value of this technique can be enhanced through knowledge integration scenarios based on real application areas. The merit and appropriateness of GIS prototype projects could be weighted against similar projects developed without GIS.

GIS prototype projects would enable identification of the issues associated with their implementation by the CEP. The identification of such issues would also contribute to decisions about whether it would be worthwhile for the CEP to acquire a GIS or not.

(v) The extension of the area covered by this case study to the whole of Wilkes Land (East Antarctica), including Pointe Geologie Archipelago.

The findings of the case study developed in Chapter V and Chapter VI of this thesis demonstrate that the representativeness of a particular ecosystem type, for instance the coastal ecosystem of Eastern Antarctica, can be assessed relying upon the habitat requirements of the species breeding and living in the area considered. The GIS methodology that was used for the Windmill Islands could be extended to any ice-free areas within the same bioregion, referred to in Chapter V as Wilkes Land. Similarly, the habitat requirements of all species breeding or occurring on Wilkes Land, including vegetation, could be analysed, providing data on their presence is collected.

For example, Pointe Geologie Archipelago is the second most important ice-free area in terms of surface after the Windmill Islands to be contained within Wilkes Land. This area could be investigated using the same methodology as applied in Chapter VI of this thesis. This would ensure that a standardised method is applied for separate jurisdictions, for instance the French and the Australian, in order to assess the representativeness of the same coastal region. It would be essential to consider the representativeness criterion (listed in Article 3.2(b) of Annex V among the criteria for protected area designation) within any management plan and zoning of the vicinities of Dumont d'Urville and Casey Stations. This would enable the formulation of alternative planning options for areas identified as representative which may be in conflict with human use. Alternative planning options may include relocation or dismantlement of human structures as in the case of the Old Casey Station, which was entirely removed.

(vi) The inclusion of all the criteria listed in Article 3.2 of Annex V (of the Protocol) in a prototype GIS project developing the Antarctic protected area system

The findings of Chapter V and VI of this thesis demonstrate that other criteria such as the wilderness and aesthetic values along with the pristine condition of the area considered can also be assessed with a GIS methodology. The other criteria listed in Article 3.2 of Annex V are: abundance and biodiversity, uniqueness, scientific value and historic value. Providing the required data was available, these could be included among the criteria previously examined in the case study. The overall outcome of this investigation would be to prioritise areas fulfilling the criteria considered in accordance with a cumulative index. Such a priority index would provide decision makers with a cartographic output illustrating the different values at stake in the decision making process when it comes to allocating an area with a particular land use.

Because the prototype GIS project described here falls within the functions of the CEP regarding the development of the Antarctic protected area system (Article 12.1(g) of the Protocol), its feasibility ought to be examined within this context, as an example of how the CEP could be provided with means of delivering informed advice to ATCMs.

(vii) The designation of Peterson Island, Shirley Island and Reeve Hill (Windmill Islands, East Antarctica) as Specially Protected Areas.

The findings of the case study show that Peterson Island, Shirley Island (adjacent to Bailey peninsula) and Reeve Hill (located on Bailey Peninsula in proximity to Casey Station) have a considerable representative value which was assessed by taking into account the habitat requirements of snow petrels and cape petrels alone. Moreover, both Peterson and Shirley Islands contain important species assemblages which were not considered in the case study (restricted to two seabirds species only). For Peterson Island, the other species to take into account are: wilson storm petrels, adelie penguins and elephant seals. Peterson Island is also a rare location in the Windmill Islands as the island offers suitable shores for (elephant seals) haul-out sites. All the protected areas of the Windmill Islands are located in the northern and central of the region and the network of protected areas is unrepresented in the southern part of the region. Peterson Island is representative of the southern part of the region and its designation as a protected area would therefore fulfil this gap.

With respect to Shirley Island, snow petrel nests have been sighted and the island also contain several adelie penguin colonies which are subject to on-going scientific studies. Considering the proximity of Shirley Island to Casey Station, an on-going increase of human impacts upon adelie penguin has been observed[344]. With respect to Reeve Hill, the snow petrel colony which was surveyed is even more subject to human interference, mainly from quarrying activities occurring at the bottom of the hill during summer and human visitation. Considering the ecological importance of the three sites and the potential for on-going interference with the species breeding in these areas, it is recommended that Peterson and Shirley Islands along with Reeve Hill be designated as SPAs.

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[344] Woehler, E.J., Penney, R.L., Creet, S.M., Burton, H.R., 1994, Impacts of human visitors on breeding success and long-term population trends in Adelie Penguins at Casey, Antarctica, *Polar Biology*, volume 14, pp. 269-274.

4. The case summarised

It may be argued that state compliance with the operation of the Protocol will not depend mainly on the structure and power of institutions nor the use of GIS within these institutions but rather on the political will of governments to enforce their national legislation that implements the Protocol. However, this approach alone is unlikely to produce the necessary standards of environmental protection which the Protocol requires, because of the disparity between Antarctic Treaty Parties with respect to their national environmental policies and logistic involvement in Antarctica. On the contrary, this thesis argues that the institutionalisation of the CEP is a preliminary condition to a standardised implementation of the Protocol throughout Antarctica. Indeed, providing the CEP with permanent staff and resources would secure a continuity which the CEP currently lacks. It is also advocated that the use of GIS in such an organisational context would enhance the operational capacity of the CEP.

The findings of this research highlight the relevance of GIS techniques for improving the network of Antarctic protected areas as well as for the containment areas of human impacts within a zonation scheme so as to prevent the uncontrolled spread of human activities. While these issues are addressed in the Madrid Protocol, the priority index methodology provides means of implementing the provisions of Annex V. This thesis shows that the use of GIS in the environmental management context of Antarctica necessarily relies upon a centralisation of information which requires institutional changes within the ATS. The experience of CCAMLR demonstrates the ability of the ATS to incorporate such changes and can be seen as a model for an effective operation of the CEP. This appears necessary considering the increase of human activities and the sporadic designation of protected areas which prevailed until the adoption of the Protocol. It is therefore argued that the way forward for the ATS is to overcome such issues and that this would ensure the effectiveness of the conservation regime described in the Protocol. To this end, this thesis proposes means of action which are aimed at policy makers within the forum of the Antarctic Treaty Consultative Meetings.

Selected Bibliography

Legal materials

Convention concerning the Protection of the World Cultural and Natural Heritage, November 16, 1972, *International Legal Materials*, 11: 1358.

Convention on the Conservation of Antarctic Marine Living Resources, May 20, 1980, *International Legal Materials*, 19: 860.

Convention on the Regulation of Antarctic Mineral Resource Activities, June 2, 1988, International Legal Materials, 27: 859.

Final Act of the Conference on the Conservation of Antarctic Marine Living Resources, Done May 20, 1980, *International Legal Materials*, 19: 837.

Official Journal of the European Community, Council Decision on 27 June 1985 on the adoption of the Commission work programme concerning an experimental project for gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community, OJ L 176, 6 July 1985.

Protocol on Environmental Protection to the Antarctic Treaty, October 4, 1991, *International Legal Materials*, 30: 1455.

Rio Declaration on Environment and Development, June 14, 1992, *International Legal Materials*, 31: 874.

United Nations, Convention on Biological Diversity, June 5 1992, *International Legal Materials* , 31: 818.

United Nations Framework Convention on Climate Change, May 9 1992, *International Legal Materials*, 31: 848.

Reports

International

ATCMs, 1990, *Final Report of the Fifteenth Antarctic Treaty Consultative Treaty Meeting, Paris 9 - 20 October, 1989,* Republic of France, 367 pp.

ATCMs, 1992, *Final Report of the Sixteenth Antarctic Treaty Consultative Meeting, Bonn, 7 - 18 October, 1991,* Federal Republic of Germany, 382 pp.

ATCMs, 1993, *Final Report of the Seventeenth Antarctic Treaty Consultative Meeting, Venice, 11 - 20 November 1992,* Rome: Ministry of Foreign Affairs, 485 pp.

ATCMs, 1994, *Final Report of the Eighteenth Antarctic Treaty Consultative Meeting, Kyoto, 11 - 22 April 1994,* Japan: Ministry of Foreigh Affairs, 313 pp.

ATCMs, 1995, *Final Report of the Nineteenth Antarctic Treaty Consultative Meeting, Seoul, 8 - 19 May 1995,* South Korea: Ministry of Foreign Affairs, 367 pp.

CCAMLR, *Schedule of Conservation Measures in Force 1989,* Hobart, Tasmania: CCAMLR Secretariat, 8 pp.

CCAMLR, *Schedule of Conservation Measures in Force 1990,* Hobart, Tasmania: CCAMLR Secretariat, 9 pp.

CCAMLR, *Schedule of Conservation Measures in Force 1990/91,* Hobart, Tasmania: CCAMLR Secretariat, 15 pp.

CCAMLR, *Schedule of Conservation Measures in Force 1991/92,* Hobart, Tasmania: CCAMLR Secretariat, 26 pp.

CCAMLR, *Schedule of Conservation Measures in Force 1992/93,* Hobart, Tasmania: CCAMLR Secretariat, 48 pp.

CCAMLR, *Schedule of Conservation Measures in Force 1993/94,* Hobart, Tasmania: CCAMLR Secretariat, 64 pp.

CCAMLR, *Schedule of Conservation Measures in Force 1995/96,* Hobart, Tasmania: CCAMLR Secretariat, 68 pp.

CCAMLR, *Schedule of Conservation Measures in Force 1996/97,* Hobart, Tasmania: CCAMLR Secretariat, 70 pp.

CCAMLR, *Report of the Fifth Meeting of the Commission,* 8-19 September 1986, Hobart: CCAMLR Secretariat, 86 pp.

CCAMLR, *Report of the Sixth Meeting of the Commission,* 26 October - 6 November 1987, Hobart: CCAMLR Secretariat, 99 pp.

CCAMLR, *Report of the Seventh Meeting of the Commission,* 24 October - 4 November 1988, Hobart: CCAMLR Secretariat, 121 pp.

CCAMLR, *Report of the Eighth Meeting of the Commission,* 6-17 November 1989, Hobart: CCAMLR Secretariat, 133 pp.

CCAMLR, *Report of the Ninth Meeting of the Commission,* 22 October - 2 November 1990, Hobart: CCAMLR Secretariat, 123 pp.

CCAMLR, *Report of the Tenth Meeting of the Commission,* 21 October - 1 November 1991, Hobart: CCAMLR Secretariat, 101 pp.

CCAMLR, *Report of the Eleventh Meeting of the Commission,* 26 October - 6 November 1992, Hobart: CCAMLR Secretariat, 99 pp.

CCAMLR,*Report of the Twelfth Meeting of the Commission,* 25 October - 5 November 1993, Hobart: CCAMLR Secretariat, 133 pp.

CCAMLR, *Report of the Thirteenth Meeting of the Commission,* 26 October - 4 November 1994, Hobart: CCAMLR Secretariat, 123 pp.

CCAMLR, *Report of the Fourteenth Meeting of the Commission,* 24 October - 3 November 1995, Hobart: CCAMLR Secretariat, 153 pp.

CCAMLR, *Report of the Fifteenth Meeting of the Commission,* 21 October - 1 november 1996, Hobart: CCAMLR Secretariat, 163 pp.

U.N. 1991. *United Nations General Assembly Records 46th Session. Report of Secretary-General on the state of the environment in Antarctica,* 25 October 1991, A46/590.

U.N. 1992f. *Protecting the Earth's Great Wilderness: Antarctica.*, New York: United Nations Department of Public Information, DPI 1222.

U.N. 1993f. *Protecting the Common Heritage of Antarctica,* New York: United Nations Department of Public Information , DPI 1375.

UNESCO-UNEP, 1974, *Final Report: Programme on Man and Biosphere (MAB) Task Force on: criteria and guidelines for the choice and establishment of biosphere reserves,* MAB Report Series n° 22, International Co-ordinating Council of the Programme on Man and the Biosphere, Paris: United Nations Educational, Scientific and Cultural Organisation, 61 pp.

UNESCO, 1995, *Operational Guides for the Implementation of the World Heritage Convention,* Intergovernmental Committee for the Protection of the World Cultural and Natural Heritage, Paris: United Nations Educational, Scientific and Cultural Organisation, 44 pp.

Governmental

Antarctic Science: The Way Forward, A Report of the Antarctic Science Advisory Committee, 1992, Department of the Environment, Sport and Territories: Commonwealth of Australia, 89 pp.

Australian National Antarctic Research Expeditions (ANARE), 1994, *Strategic Plans 1995-2000* , Department of the Environment, Sport and Territories: Commonwealth of Australia, 100 pp.

Australian Science and Technology Council, 1990, *Environmental Research in Australia: the Issues. A Report to the Prime Minister by the ASTEC,* Canberra: Australian Government Publishing Service, 87 pp.

Cocks, K.D., Walker, P.A., 1986, *Using ARIS to Evaluate the Biogeographical Spread of Australia's Biosphere Reserves,* Commonwealth Scientific and Industrial Research Organisation (CSIRO) Division of Water and Land Resources Technical Memorandum 86/22, Canberra, Australia.

Deprez, P.P.; Arens, M.; Locher, H., 1994, *Identification and Preliminary Assessment of Contaminated Sites in the Australian Antarctic Territory,* Australian

Antarctic Division, Commonwealth Department of the Environment, Sports and Territories, 63 pp.

Method Papers: East Gippsland and Central Highlands Joint Forests Projects, Volume 2-Cultural Values, 1994, Australian Heritage Commission-Department of Conservation and Natural Resources, Victoria, 34 pp.

Tasmanian Wilderness World Heritage Area Management Plan, 1992, Department of Parks, Wildlife and Heritage, Tasmania, 135 pp.

Organisations

Lesslie, R.,Taylor, D., Maslen, M., 1993, *National Wilderness Inventory: Handbook of Principles, Procedures and Usage. A report to the Australian Heritage Commission,* Australian Heritage Commission, 18 pp.

Lesslie, R., Abrahams, H., Maslen, M., 1992, *National Wilderness Inventory: Stage III: Wilderness Quality on Cape York Peninsula, A Report to the Australian Heritage Commission,* Australian Heritage Commission, 46 pp.

Onsrud, H.J., Rushton, G., 1992, *Institutions Sharing Geographic Information,* Technical Report 92-5, National Center for Geographic Information and Analysis, USA, 45 pp.

Vincent, W.F., (ed.), 1996, *Environmental Management of a Cold Desert Ecosystem: the Mc Murdo Dry Valleys, Report of a National Science Foundation Workshop held at Santa Fe, New Mexico, 14-17 March 1995,* Desert Research Institute, University of Nevada, special publication, 57 pp.

Books

Afifi, A.A.; Clark, V.; 1996, *Computer-Aided Multivariate Analysis,* London: Chapman & Hall, 455 pp.

Andresen, S., Ostreng, W., 1989, *International Resource Management: The Role of Science and Politics,* London: Belhaven Press, 288 pp.

Aronoff, S., 1989, *Geographic Information Systems: A Management Perspective,* Ottawa: WDL Publications, 289 pp.

Auburn, F.M., 1982, *Antarctic Law and Politics*, Canberra: Croom-Helm (Australia), 361 pp.

Belbin, L., 1995, *PATN Pattern Analysis Package: Users Guide and Technical Reference*, CSIRO Australia, Division of Wildlife and Ecology, 79 pp. and 220 pp.

Benninghoff, W.S., Bonner, W. N., 1985, *Man's Impact on the Antarctic Environment: a Procedure for Evaluating the Impacts from Scientific/Logistic Activities*, Cambridge: SCAR, Scott Polar Research Institute, 56 pp.

Bonner, W.N., Walton, D.W. H., 1985, *Key Environments: Antarctica*, Oxford: Pegramon Press, 381 pp.

Bonner, W.N., Lewis Smith, R.I., (eds.), 1985, *Conservation Areas in the Antarctic, A review prepared by the Sub committee on Conservation of SCAR Working Group on Biology*, Cambridge: Scott Polar Research Institute.

Burrough, P.A., 1986, *Principles of Geographical Information Systems for Land Resources Assessment*, Oxford: Clarendon Press, 194 pp.

Bracken, I., Webster, C., 1990, *Information Technology in Geography and Planning*, London: Routledge, 444 pp.

Buckley, R., 1991,*Perspectives in Environmental Management*, Berlin-Heidelberg: Springer-Verlag, 276 pp.

Caldwell, L.K.,1990, *Between Two Worlds: Science, the Environmental Movement and Policy Choice* , Cambridge: Cambridge University Press, 224 pp.

Caldwell, L.K., 1990, *International Environmental Policy*, Second Edition, London: Duke University Press, 460 pp.

Campbell, H; Masser, I., 1995, *GIS and Organizations: How Effective are GIS in Practice*, London: Taylor & Francis, 178 pp.

Carroll, J.E., (ed.), 1988, *International Environmental Diplomacy* , Cambridge: Cambridge University Press, 291 pp.

Croxall, J.P., (ed.), 1991, *Seabird: Status and Conservation, a Supplement* (Technical publication n° 11), Cambridge: International Council for Bird Preservation.

Dunlop, C., Kling, R., (eds.) , 1991, *Computerization and Controversy: Value Conflicts and Social Choices*, San Diego: Academic Press, 758 pp.

Elliott, L.M., 1994, *International Environmental Politics: Protecting the Antarctic*, New York: St Martin's Press, 336 pp.

Elzinga, A., (ed.), 1992, *Changing Trends in Antarctic Research,* Dordrecht: Kluwer Academic Publishers, 152 pp.

Fisher, M.N., Nijkamp, P., 1993, *Geographic Information System, Spatial Modelling and Policy Evaluation,* Berlin: Springer-Verlag, 280 pp.

Funtowicz, S.O., Ravetz, J.R., 1990, *Uncertainty and Quality in Science for Policy*, Dordrecht: Kluwer Academic Publishers, 229 pp.

Gauch, H.G., 1982, *Multivariate Analysis in Community Ecology*, Cambridge: Cambridge University Press, 298 pp.

Goodchild, M. F., 1996, *GIS and Environmental Modeling: Progress and Research Issues*, Fort Collins, CO: GIS World Books, 486 pp.

Hair, J.F.; Anderson, R.F.; Tatham, R.L.; Black, W.C., 1995, *Multivariate Data Analysis with Readings*, Englewood Cliffs, N.J: Prentice Hall, 745 pp.

Handbook of the Antarctic Treaty System, 1994, Eighth edition, Washington D.C: U.S Department of State, 2300 pp.

Haas, E. B., 1990, *When Knowledge is Power: Three Models of Change in International Organizations*, Berkeley: University of California Press, 266 pp.

Hendee, J.C., Stankey, G.H., Lucas, R.C., 1978, *Wilderness Management*, U.S Department of Agriculture, Forest Service Miscellaneous Publication n°1365, 381 pp.

Heit, M., Shortreid, A., (eds.), 1991, *GIS Applications in Natural Resources*, Fort Collins, Colorado: GIS World, 381 pp.

Herr, R. A., Hall, H. R., Haward, M. G., (eds.), 1990, *Antarctica's Future:*

Continuity or Change? Hobart, Tasmania: Australian Institute of international Affairs, 338 pp.

Holdgate, M.W, (eds.), 1970, *Antarctic Ecology,* 2 volumes, London: Academic Press,

Hurrell, A., Kinsbury, B.,eds.), 1992, *The International Politics of the Environment: Actors, Interests, and Institutions* , Oxford: Clarendon Press, 492 pp.

Institute of Environmental Assessment and the Landscape Institute, 1995, *Guidelines for Landscape and Visual Impact Assessment,* E & FN Spon, London: Chapman & Hall, 126 pp.

IUCN, 1991, *A Strategy for Antarctic Conservation,* Gland and Cambridge: IUCN - The World Conservation Union, 84 pp.

Jakeman, A. J., Beck, M. B., McAleer, M. J., (eds.), 1993, *Modelling Change in Environmental Systems,* Chichester, England: Wiley, 584 pp.

Jorgensen-Dahl, A; Ostreng, W, (eds.), 1991,*The Antarctic Treaty System in World Politics*; Basingstoke: MacMillan Academic and Professional, 475 pp.

Joyner, C., 1995,*CRAMRA's Legacy of Legitimacy: Progenitor to the Madrid Environmental Protocol,* Antarctic and Southern Ocean Law and Policy Occasional Papers 7, Hobart: Institute of Antarctic and Southern Ocean Studies, University of Tasmania, pp. 2-38.

Joyner, C., 1992, *Antarctica and the Law of the Sea,* Dordrecht: Martinus Nijhoff Publishers, 302 pp.

Joyner, C., Chopra, S.K., (eds.), 1988, *The Antarctic Legal Regime,* Dordrecht: Martinus Nijhoff Publishers, 288 pp.

Keage, P.L., 1986, *Antarctic Protected Areas: Future Options,* Environmental Studies Occasional Paper 19, Centre for Environmental Studies, University of Tasmania, Hobart, Tasmania, 109 pp.

Kerry, K.R., Hempel, G., (eds.), 1990, *Antarctic Ecosystems: Ecological Change and Conservation,* Berlin: Springer-Verlag, 427 pp.

Kiss, A., Shelton, D., 1991, *International Environmental Law,* Ardsley-on-Hudson, New York: Transnational Publishers Inc., 541 pp.

Laws, R.W.,(ed.), 1984,*Antarctic Ecology,* 2 volumes, London: Academic Press, 852 pp.

Lee, K. N., 1993, *Compass and Gyroscope: Integrating Science and Politics for the Environment,* Washington D.C: Island Press, 243 pp.

Longley, P., Batty, M., (eds.), 1996, *Spatial Analysis: Modelling in a GIS Environment,* Cambridge: GeoInformation International, 385 pp.

Lucas, P.H.C., 1992, *Protected Landscapes,* London: Chapman & Hall, 297 pp.

Maguire, D.J., Rhind, D.W., (eds.), 1991, *GIS Principles and Applications,* volume 2, Harlow: Longman Scientific & Technical, 447 pp.

Masser, I., Onsrud, H.L., 1993, *Diffusion and Use of Geographic Information Technologies,* Dordrecht: Kluwer Academic Publishers, 349 pp.

Michener, W. K., Brunt, J. W., Stafford, S. G., (eds.), 1994, *Environmental Information Management and Analysis: Ecosystems to Global Scales,* London: Taylor & Francis, 428 pp.

Miller, R. I., (ed.), 1994, *Mapping the Diversity of Nature,* London: Chapman & Hall, 178 pp.

Monkhouse, F.J, 1970, *A dictionary of Geography,* London: Edward Arnold, 378 pp.

Mounsey, H., Tomlinson, R., (eds.), 1988, *Building Databases for Global Science,* London: Taylor & Francis, 419 pp.

Murray, M.D., Luders, D.J., 1990, *Faunistic Studies at the Windmill Islands, Wilkes Land, East Antarctica,* ANARE Research Notes 73, Australian Antarctic Division, 37 pp.

Newton, P. W., Zwart, P. R., Cavill, M. E., (eds.), 1992, *Networking Spatial Information Systems,* London: Belhaven Press, 299 pp.

O'Riordan, T., 1995, *Environmental Science for Environmental Management*, Harlow: Longman Scientific & Technical, UK, 369 pp.

Priestley, R., Adie, R., de Q. Robin, (eds.), 1964, *Antarctic Research,* London: Butterworths, 360 pp.

Ramsay, R.; Rowe, G.C., 1995. *Environmental Law and Policy in Australia: Text and Materials,* Sydney: Butterworths, 706 pp.

Rogerson, P.A, Fotheringham, S., (eds.), 1994, *Spatial Analysis and GIS,* London: Taylor & Francis, 281 pp.

Rothwell, D.R., 1996, *The Polar Regions and the Development of International Law,* Cambridge: Cambridge University Press, 498 pp.

Rothwell, D.R., 1992, *The Madrid Protocol and its Relationship with the ATS,* Antarctic and Southern Ocean Law and Policy Occasional Papers 5, Hobart: University of Tasmania, 34 pp.

Sand, P.H., (ed.), 1992, *The Effectiveness of International Environmnental Agreements,* Cambridge: Grotius Publications Limited, 539 pp.

Sand, P.H., 1990, *Lessons Learned in Global Environmnental Governance,* Washington D.C: World Resources Institute, 65 pp.

Scott, J. M., Davis, F., Csuti, B., Noss, R., Butterfield, B., Groves, C., Anderson, H., Caicco, S., D'Erchia, F., Edwards, T. C., Ulliman, J., Wright, R.G., 1993, *Gap Analysis: A Geographic Approach to Protection of Biological Diversity,* Wildlife Monograph n°123, The Wildlife Society Inc., 41 pp.

Sherman, K., Alexander, L.M., Gold, B.D., (eds.), 1993, *Large Marine Ecosystems: Stress, Mitigation and Sustainability,* Washington, D.C: American Association for the Advancement of Science, 376 pp.

Spellerberg, I.A., 1992, *Evaluation and Assessment for Conservation: Ecological Guidelines for Determining Priorities for Nature Conservation,* London: Chapman & Hall, 236 pp.

Star, J., Estes, J., 1990, *Geographic Information Systems: An Introduction,* Englewood Cliffs, NJ: Prentice Hall, 303 pp.

Schwerdtfeger, W., 1984, *Weather and Climate of the Antarctic,* Amsterdam: Elsevier, 261 pp.

Susskind, L., 1994, *Environmental Diplomacy,* Oxford: Oxford University Press, 201 pp.

Triggs, G.D., (ed.), 1987, *The Antarctic Treaty Regime,* Cambridge: Cambridge University Press, 237 pp.

Triggs, G.D., 1986, *International Law and Australian Sovereignty in Antarctica,* Sydney: Legal Books Pty, 403 pp.

Usher, M. E., (ed.), 1986, *Wildlife Conservation Evaluation,* London: Chapman & Hall, 394 pp.

Verhoeven, J., Sands, P., Bruce, M., (eds.), 1992, *The Antarctic Environment and International Law,* London: Graham and Trotman, 228 pp.

Vicuna, F. O., (ed.), 1983, *Antarctic Resources Policy,* Cambridge: Cambridge University Press, 355 pp.

Warham, J., 1990, *The Petrels: Their Ecology and Breeding Systems,* London: Academic Press, 440 pp.

Watts, A., 1992, *International Law and the Antarctic Treaty System,* Cambridge: Grotius Publications, 469 pp.

Westra, L., Lemons, J., (eds.), 1995, *Perspectives on Ecological Integrity,* Dordrecht: Kluwer Academic Publishers, 279 pp.

Wolfrum, R., 1991,*The Convention on the Regulation of Antarctic Mineral Resource Activities*. Berlin: Springer-Verlag, 205 pp.

Wolfrum, R., 1988, *Antarctic Challenge III: Conflicting Interests, Cooperation, Environmental Protection and Economic Development,* Berlin: Duncker & Humblot, 589 pp.

Worrall, L., (ed.), 1991,*Spatial Analysis and Spatial Policy using Geographic Information Systems,* London: Belhaven Press, 235 pp.

Yin, R.K., 1994, *Case Study Research: Design and Methods,* 2nd Edition, London: Sage, 170 pp.

Zonneveld, I.S; Forman, R.T.T (eds.), 1990, *Changing Landscapes: An Ecological Perspective,* N.Y: Springer-Verlag, 234 pp.

Conference Proceedings & Symposiums

Conserving the Natural Heritage of the Antarctic Realm: Proceedings of the 29th Working Session of the IUCN's Commission on National Parks and Protected Areas, Wairakei, N.Z, 16-21 August 1987, IUCN, Gland, Switzerland.

Drewry, D. J., Laws, R. M., Pyle, J. A., (eds.), 1993, *Antarctica and Environmental Change: Proceedings a of a discussion held on 20-21 May 1992,* London: Royal Society, 137 pp.

Global Natural Resource Monitoring and Assessment, Preparing the 21st Century, Proceedings of the International Conference and Workshop 24-30 Sept. 1989, American Society for Photogrammetry and Remote Sensing, USA (1990), 1178 pp.

Handmer, J., Wilder, M., (eds.), 1993, *Towards a Conservation Strategy for the Australian Antarctic Territory: The 1993 Fenner Conference on the Environment,* Australian National University, Canberra: Centre for Resource and Environmental Studies, 216 pp.

Herman, T.B., Bondrup-Nielsen, S., Willison, M., Munro, N.W.P., (eds.), *Ecosystem Monitoring and Protected Areas: Proceedings of the 2nd conference on Science and the Management of Protected Areas, Dalhousie University, Halifax, 16-20 May 1994,* Science and Management of Protected Areas Association, Centre for Wildlife and Conservation Biology, Acadia University, Nova Scotia, Canada, 575 pp.

Jackson, A.W., (ed.), 1996, *On the Antarctic Horizon: Proceedings of the International Symposium of the Future of the Antarctic Treaty System, Ushuaia, Argentina, 20 to 24 March 1995,* Hobart: Australian Antarctic Foundation, 116 pp.

Lewis Smith, R.I., Walton, D.H.W., and Dingwall, P.R., (eds.), 1994, *Developing the Antarctic Protected Area System, Proceedings of the SCAR/IUCN Worshop on Antarctic Protected Areas, Cambridge, Uk, 29 June - 2 July 1992,* Gland and Cambridge: IUCN, 137 pp.

Power, J.M., Murray Strome, Daniel, T.C., (eds.), 1995, *Proceedings Decision-Support 2001,* Toronto September 12-16, 1994, American Society for Photogrammetry and Remote Sensing, 1158 pp.

Verner, J., Morrison, M. L., Ralph, C. J., (eds.), 1986, *Wildlife 2000: Modeling Habitat Relationships of Terrestrial Vertebrates, Based on an International Symposium held at Stanford Sierra Camp, Fallen Leaf Lake, California, 7-11 October 1984,* Madison: University of Wisconsin Press, 470 pp.

Willison, J.H.M.,Bondrup-Nielsen, S., Drysdale, C., Herman, T.B., Munro, N.W.P., Pollock, T.L., (eds.), 1992, *Science and Management of Protected Areas, Proceedings of an International Conference held at Acadia University, Nova Scotia, Canada, 14-19 May 1991,* Amsterdam: Eslevier, 633 pp.

Articles

Angel, M. V., 1987, Criteria for Protected Areas and Other Conservation Measures in the Antarctic Region, *Environment International,* vol. 13, pp. 105-114.

Aschenbach, R.J., 1991, GIS as a Decision Making Tool, *Ohio State Law Journal,* volume 52, part I., pp. 350-368.

Batisse, M.,1982, The Biosphere Reserve: a Tool for Environmental Conservation and Management, *Environmental Conservation,* volume 9, n° 2, pp. 101-111.

Beck, P., 1995, The United Nations and Antarctica, 1994: the Restoration of Consensus ? *Polar Record,* volume 31, n°179, pp. 419-424.

Beck, P., 1994, The United Nations and Antarctica, 1993: Continuing Controversy about the UN's Role in Antarctica, *Polar Record,*volume 30, n°175, pp. 257-264.

Beck, P., 1993, The United Nations and Antarctica, 1992: Still Searching for that Elusive Convergence of View, *Polar Record,* volume 29, n° 171, pp. 313-320.

Beck, P., 1992, The 1991 UN Session: the Environmental Protocol Fails to Satisfy the Antarctic Treaty System's Critics, *Polar Record,*volume 28, n°167, pp. 307-314.

Bedwart, M., Pressey, R.L., Keith, D.A., 1992, A New Approach for Selecting Fully Representative Reserve Networks: Addressing Efficiency, Reserve Design and Land Suitability with an Iterative Analysis, *Biological Conservation*, volume 62, pp. 115-125.

Blay, S., 1992, New Trends in the Protection of the Antarctic Environment, *American Journal of International Law*, volume 86, pp. 377-399.

Blay, S., Piotrowicz, R., 1993, Biodiversity and Conservation in the 21st Century: A Critique of the Earth Summit 1992, *Environmental Law and Planning Journal,* volume 10, pp.450-469.

Boczek, B.A., 1984, The Protection of the Antarctic Ecosystem: A Study of International Environmental Law, *Ocean Development and International Law Journal*, volume 13., n° 3, pp. 347-425.

Buckland, S. T., Elston, D. A., 1993, Empirical Models for the Spatial Distribution of Wildlife, *Journal of Applied Ecology*, volume 30, pp. 478-495.

Burgess, J.S., Spate, A.P., Norman, F.I., 1992, Environmental Impacts of Station Development in the Larsemann Hills, Princess Elizabeth Land, Antarctica, *Journal of Environmental Management*, volume 36, 287-299.

Burton, S.J., 1979, New Schemes of the Antarctic Treaty: Toward International Legal Institutions Governing Antarctic Resources,*Virginia Law Review*, volume 65, n° 3, pp. 421-512.

Champ, M. A., Flemer, D. A., Landers, D. H., Ribic, C., DeLaca, T., 1992, The Roles of Monitoring and Research in Polar Environments, *Marine Pollution Bulletin*, volume 25, pp. 9-12.

Chastel, O., Weimerskirch, H., Jouventin, P., 1993, High Annual Variability in Reproductive Success and Survival of an Antarctic Bird, the Snow Petrel Pagodroma nivea, *Oecologica*, volume 94, pp. 278-285.

Cocks, K.D., Walker, P.A., Parvey, C.A, 1988, Evolution of a Continental-Scale Geographical Information System, *International Journal of Geographical Information Systems,* volume 2, n° 3, pp. 263-280.

Croxall, J.P., 1987, The Status and Conservation of Antarctic Seals and Seabirds: a Review. *Environmental International,* volume 13, pp. 55-70.

Dalziell, J., Goldsmith, L.,1994, World Park Antarctica: Does It Have a Future?, *Forum for Applied Research and Public Policy,* volume 9, n° 1, pp.71-75.

Dubayah, R., Rich, P.M., 1995, Topographic Solar Radiation Models for GIS, *International Journal of Geographical Information Systems,* volume 9, n°4, pp. 405-419.

Frank, R., 1983, The CCAMLR, *Ocean Development and International Law Journal,* volume 13, n° 3, pp. 291-345.

Gimblett, H. R., 1987, Procedure for Assessing Visual Quality for Landscape Planning and Management, *Environmental Management,* volume 11, n° 3, pp. 359-367.

Harris, C.M., 1994, Standardisation of Zones within Specially Protected and Managed Areas under the Antarctic Environmental Protocol, *Polar Record,* volume 30, n°175, pp. 283-286.

Harris, C.M., 1994, Protected Areas Review: McMurdo Sound, Ross Sea, *Polar Record,* volume 30, n°174, pp.189-192.

Harris, C. M., 1992, Environmental Management in Antarctica: Instruments and Institutions, *Marine Pollution Bulletin,* volume 25, pp. 239-249.

Harrison, J., 1983, Maintaining a Database on the World's Protected Areas, *Parks,* volume 7, n° 4, pp. 3-5.

Holdgate, M.W., 1977, Terrestrial Ecosystems in the Antarctic, *Philosophical Transactions of the Royal Society of London. B.* volume279, pp. 5-25.

Howard, M., 1989, The Convention on the Conservation of Antarctic Marine Living Resources: A Five-Year Review, *International Comparative Law Quarterly,* volume 38, pp. 109-149.

Husby, E., 1993, GRID-Arendal Bridges the Gap, *GIS Europe,* volume 2, n° 6, pp. 30-33.
Kamenev, V.M., 1988, Ecology of the Cape Pigeon and the Snow Petrel, *Polar Geography and Geology,* volume 12, n°3, pp. 227-237.

Keage, P. L, Hay, P. R., Russell. J. A., 1989, Improving Antarctic Management Plans, *Polar Record,* volume 25, n°155, pp. 309-314.

Kirkpatrick, J.B., 1983, An Iterative Method for Establishing Priorities for the Selection of Nature Reserves: An Example from Tasmania, *Biological Conservation,* volume 25, pp. 127-134.

Knutson, M. G., Leopold, D. J., Smardon, R. C., 1993, Selecting Islands and Shoals for Conservation Based on Biological and Aesthetic Criteria, *Environmental Management,* volume 17, n° 2, pp. 199-210.

Kock, K. H., 1994, Fishing and Conservation in Southern Waters, *Polar Record* volume 30, n°172, pp. 3-22.

Kriwoken, L. K., 1994, Antarctic Environment and Joint Protection, *Forum for Applied Research and Public Policy,* volume 9, n° 1, pp.86-89.

Kriwoken, L. K., 1989, Antarctic Environmental Planning and Management: Conclusions from Casey, Australian Antarctic Territory, *Polar Record,* volume 27, n°160, pp. 1-8.

Lajeunesse, D., Domon, G., Drapeau, P., Cogliastro, A., Bouchard, A., 1995, Development and Application of an Ecosystem Management Approach for Protected Natural Areas, *Environmental Management,* volume 19, n° 4, pp. 481-495.

Lesslie, R. G., Mackey, B. G., Preece, K., 1988, A Computer-Based Method of Wilderness Evaluation, *Environment International,* volume 15, n° 3, pp. 225-232.

Lesslie, R. G., Taylor, S. G., 1985, The Wilderness Continuum Concept and its Implications for Australian Wilderness Preservation Policy, *Biological Conservation,* volume 32, pp. 309-333.

Lyons, D., 1993, Environmental Impact Assessment in Antarctica under the

Protocol on Environmental Protection, *Polar Record*, volume 29, n°169, pp. 111-120.

Mackey, B.G., Nix, H. A., Stein, J. A., Cork, S. E., 1989, Assessing the Representativeness of the Wet Tropics of Queensland World Heritage Property, *Biological Conservation*, volume 50, pp. 279-303.

Mackey, B. G., Nix, H. A., Hutchinson, M. F., MacMahon, J. P., 1988, Assessing representativeness of Places for Conservation Reservation and Heritage Listing, *Environmental Management*, volume 12, n° 4, pp. 501-514.

Margules, C., Usher, M. B., 1981, Criteria Used in Assessing Wildlife Conservation Potential: A Review, *Biological Conservation*, volume 21, pp. 79-109.

Murray, D.M., von Gadow, K., 1991, Prioritizing Mountain Catchment Areas, *Journal of Environmental Management*, volume 32, pp. 357-366.

Nicol, S., 1991, CCAMLR and its Approaches to Management of the Krill Fishery, *Polar Record*, volume 27, n°162, pp. 229-236.

Palmer, G., 1992, New Ways to Make International Environmental Law, *American Journal of International Law*, volume 86, pp. 259-283.

Parker, S., Cocklin, C., 1993, The use of Geographical Information Systems for Cumulative Environmental Effects Assessment, *Computers, Environments and Urban Systems*, volume 17, pp. 393-407.

Pereira, J.M.C., Itami, R.M., GIS-Based Habitat Modeling Using Logistic Multiple Regression: A Study of the Mt. Graham Red Squirrel, *Photogrammetric Engineering & Remote Sensing*, volume 57, n°11, November 1991, pp. 1475-1486.

Perrin de Richambaut, M., 1995, La Nouvelle Ere du Traite sur l'Antarctique, *Acta Geographica*, n° 102, pp. 36-43.

Pressey, R.L., Nicholls, A.O., 1989, Efficiency in Conservation Evaluation: Scoring versus Iterative Approaches, *Biological Conservation*, volume 50, pp. 199-218.

Smith, T.R., Sudhakar Menon, Star, J.L. and Estes, J.E., 1987, Requirements and

Principles for the Implementation and Construction of Large-Scale Geographic Information Systems, *International Journal of Geographical Information Systems*, volume 1, nº 1, pp.13-31.

Smith, P., Theberge, J., 1987, Evaluating Natural Areas Using Multiple Criteria: Theory and Practice, *Environmental Management*, volume 11, nº 4, pp. 447-460.

Smith, P., Theberge, J., 1986. A Review of Criteria for Evaluating Natural Areas, *Environmental Management*, volume 10, nº6, pp. 715-734.

Theberge, J. B., 1989, Guidelines to Drawing Ecologically Sound Boundaries for National Parks and Nature Reserves, *Environmental Management*, volume 13, nº 6, pp. 695-702.

Thompson, J.W., Cooper, A.P.R., 1993, Review of the SCAR Antarctic Digital Topographic Database, *Antarctic Science*, volume 5, nº3, pp. 239-244.

Udvardy, M.D.F.,1975, *A Classification of the Biogeographical Provinces of the World*, IUCN Occasional Paper nº 1196, Gland: IUCN.

Usher, M.B., Edwards, M., 1986, The Selection of Conservation Areas in Antarctica: an Example using the Arthropod Fauna of Antarctic Islands, *Environmental Conservation* , volume 13, nº 2, pp. 115-122.

van Franeker, J.A.; Bell, P.J., Montague, T.L., 1990. Birds of Ardery and Odbert Islands, Windmill Islands, Antarctica, *Emu*, volume 90, pp. 74-80.

von Bennekom, S., 1992, *A New Regime to Protect the Antarctic Environment*, Leiden Journal of International Law, volume 5, nº1, pp. 33-52.

Walton, D.W.H., Shears, J., 1994, The Need for Environmental Monitoring in Antarctica: Baselines, Environmental Impact Assessments, Accidents and Footprints, *International Journal of Environmental and Analytical Chemistry*, volume 55, pp. 77-90.

Welgan, P., 1992, GIS and the Law: GIS Plays Key Role in Maritime Conflict, *GIS World*, volume 5, nº 8, pp. 62-64.

Woehler, E.J., Penney, R.L., Creet, S.M., Burton, H.R., 1994, Impacts of human Visitors on Breeding Success and Long-Term Population Trends in Adelie

Penguins at Casey, Antarctica, *Polar Biology*, volume 14, pp. 269-274.

Woehler, E.J., Johnstone, G.W., 1991, Status and Conservation of the Seabirds of the Australian Antarctic Territory, *ICBP Technical Publication*, n° 11, pp. 279- 308.

Woehler, E.J., 1990, The Distribution of Seabird Biomass in the Australian Antarctic Territory: Implications for Conservation, *Environmental Conservation*, volume 17, n° 3, pp. 256-261.

Other unpublished materials

Australian Antarctic Foundation, *A Conservation Strategy for the Australian Antarctic Territory*, Draft 13 October 1993, 81 pp.

Cordonnery, L., 1992, *La Diplomatie de l'Environnement en Antarctique*, Unpublished D.E.A Thesis, University of Paris I - La Sorbonne: Department of Political Sciences, 111 pp.

Environmental Monitoring in Antarctica, a discussion document prepared by COMNAP and SCAR, March 1992, 23 pp.

Harris, C.M., 1993, *Environmental Management in Antarctica using Geographical Information Systems*, Unpublished PhD Thesis, University of Cambridge, U.K, 276 pp.

Knowles, B., 1990, *The Green, White Wilderness: Applying Ecophilosophical Principles to the Management of Antarctica's Wilderness*, Centre for Environmental Studies, Department of Geography, University of Tasmania, Australia, 70 pp.

Zwart, P. R., 1994, *Land Information Systems and the Policy Process*, Unpublished PhD Thesis, University of Tasmania, Australia, 271 pp.